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The Role of Shock-Testing Machines in Design

By C. E. CREDE. (From *Mechanical Engineering, U.S.A.*, Vol. 76, No. 7, July 1954, pp. 564-567, 6 illustrations.)

SHOCK-TESTING machines are used primarily for testing equipment intended for installation in military vehicles, aircraft, and ships, and for testing equipment which is to be transported. The shock originates generally from a large force suddenly applied to the structure or housing which supports the equipment. A shock motion usually embodies a significant displacement and a sudden change in velocity; in most instances, it is oscillatory in nature and includes several apparent frequencies. These characteristics are reproduced in shock-testing machines by mounting the equipment under test to a structure which experiences a sudden change in velocity.

Few measurements of shock during actual service conditions were made during the early days of the development of shock-testing machines. As time and facilities became available, and measurement techniques were refined, an increasing volume of data on the shock experienced in service became available. As this quantitative information has increased in volume, the problem of those engaged in shock testing and in designing to withstand shock appears to have increased also. With the accumulation of data has come a change in viewpoint. There has arisen a tendency to look upon a shock-testing machine not as a means of causing a certain type and degree of damage to equipment but rather as of reproducing certain numerical parameters found in the measurement of shock.

A shock test should be considered primarily as a means of rejecting equipment which is not sufficiently rugged to withstand the rigours of service. The ability of equipment to withstand service conditions can be evaluated only by a study of experience with equipment during service. Such a study should be approached statistically, and the results should be directed towards separating qualified from the unqualified equipment. If a shock test separates the equipment in a similar manner, it may be considered to simulate the shock encountered in actual service.

DESIGNING EQUIPMENT TO WITHSTAND SHOCK

First attempts at designing equipment to withstand shock were based on the assumption that the required strength could be calculated directly from the measured maximum acceleration of the supporting structure. In other words, using the equation $F = ma$, the maximum force F acting on a structure of known mass m could be determined by measuring the maximum acceleration a of the supporting structure. The work of Frankland, Mindlin, and others during World War II was of tremendous importance in proving this concept false and in starting new thinking along more rational lines. The essence of the current approach to this problem is the recognition that the effect of the shock upon equipment is of much greater importance than the characteristics of the shock itself.

A concept of damage resulting from shock may be visualised by referring to the idealised equipment shown in Fig. 1. This equipment consists of a housing containing structural members exemplified by the cantilever beam. The severity of the shock is evidently indicated by the maximum stress in the beam. If the beam were infinitely rigid, the mass at the end of the beam would have the same acceleration as the housing, and the maximum stress in the beam would be directly proportional to the maximum acceleration of the housing. Actually, however, the beam deflects and the acceleration of the supported mass differs from that of the housing. As a result, the maximum stress in the beam generally is a function not only of the shock motion but also of the properties of the beam.

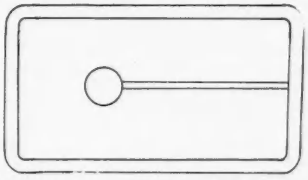


Fig. 1. **Schematic representation of idealised equipment.**

This principle may be refined by stating that, for a given shock motion and to a first approximation, all beams of the same fundamental natural frequency will experience equal maximum acceleration. This maximum acceleration is commonly expressed as a dimensionless multiple of the gravitational acceleration. If the stress in a structural member during static conditions is known, the maximum dynamic stress may be calculated by multiplying the static stress by the maximum acceleration, expressed dimensionlessly.

The problem of the machine designer is to correlate the design of the actual equipment with the idealised structure shown in Fig. 1. A promising method has been suggested to aid designers in determining the maximum stress in a machine member. This method employs response spectra. The response spectrum for a given shock motion may be defined as the maximum acceleration of the load on the cantilever beam in Fig. 1, expressed as a function of the fundamental natural frequency of the beam.

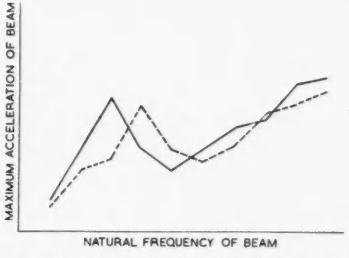


Fig. 2. **Graphical representation of typical response spectra.**

Response spectra may be expressed graphically, as shown in Fig. 2 for two typical shock motions. The peaks in the curves of Fig. 2 occur when the natural frequency of the cantilever beam coincides with a prominent frequency of the shock motion. A transient type for resonance then occurs. If the response spec-

trum for a particular shock motion is known, the maximum stress in any beam may then be calculated, using the known beam natural frequency and maximum acceleration of the load on the end of the beam.

Obtaining Response Spectra

Various means are available for obtaining response spectra. A record of the shock motion is required, expressed in terms of displacement velocity, or acceleration, as a function of time. It is then necessary to determine the response of a simple system to this shock motion, for a wide range of natural frequencies of the system. This can be done graphically or numerically, but the process is laborious. A more practical procedure is to employ a mechanical or electrical analog. Most of the response spectra available have been obtained by analog methods.

A major advantage of the spectrum method is that the most laborious portion of the design work is finished when the response spectrum has been obtained. The spectrum may be used repeatedly for all structures and remains continuously valid.

A mechanical instrument which makes it possible to obtain response spectra without recording the time history of the shock motion has been proposed recently. Such an instrument comprises a framework, supporting several cantilever beams of different natural frequencies, and means of recording the maximum deflection of each beam. When used in the laboratory, the instrument is mounted on the shock-testing machine in the same manner as the equipment to be tested. The recorded maximum deflections of the beams thus indicate the effect of the shock, rather than measure its characteristics. The results become available as a table or graph of maximum deflections of simple systems of known natural frequencies. The maximum accelerations of these systems may be computed from the measured maximum deflections, and the response spectrum for the shock motion may be plotted directly.

Limitations in Use of Shock Spectra

One of the limitations of the method using response spectra is its conservatism. An analysis of test results shows that the stresses predicted by the response spectra would often cause failure if they were the result of static loads. The reason for the discrepancy is not entirely clear. One possible explanation is that the strength of certain materials may be greater under dynamic than under static conditions. Another explanation, perhaps more plausible, is that slight yielding of the member occurs during the shock. Although the yielding would not be discernible without a careful examination, it would introduce sufficient damping and non-linearity to make the response spectrum partially inapplicable. It has not been established that use of response spectra always gives conservative results. More experience is required in interpreting response spectra, to attain optimum design of machine members.

Several years ago the author reviewed a large number of Bureau of Ships' reports on failures of equipment during shock tests. An attempt to correlate these failures with the deflection of simple cantilever beams as determined experimentally was not notably successful, because the damaged members were difficult to consider as single-degree-of-freedom systems. The discrepancy with the single-degree-of-freedom concept was the result of many diverse factors, such as (1) distributed mass of structural members, (2) elastic coupling with one or more other systems, (3) unknown constraints, and (4) materials whose properties were not well known, particularly in the presence of stress concentration.

Qualitative Approach to Equipment Design

The most successful designers of shock-resistant equipment have made but little use of the known response of simple systems as an indication of the required strength of the equipment. The procedure which has produced the best results is to follow established principles in the design of shock-resistant equipment and to conduct frequent tests to determine required strength. This is primarily a qualitative, rather than a quantitative, problem. Several applicable principles have become established as a result of an analysis of many successful designs.

Inasmuch as a shock test causes a transient response of structural members of the equipment, some inconsistencies in test results may be expected as a result of random combinations of the transients. For development work, it has been found expedient to subject the equipment either to a greater number of tests of the specified magnitude, or to tests of magnitude greater than that specified. The " factor of safety " introduced in this manner often proves worth-while in avoiding embarrassment when subjecting the equipment to final contractural qualification tests.

Establishing of Contract Requirements

It is extremely important that shock-testing specifications be definite and explicit. Equivalent tests conducted at different testing agencies must produce substantially the same result or contractural difficulties arise. From a purely practical viewpoint, this requirement overshadows all others in the administration of shock-testing procedures. Tests thus tend to become arbitrary, and initial considerations leading to establishing the testing specification tend to become lost as time goes on.

It is of great importance that shock-testing standards be established wisely, and only after a thorough study of all pertinent factors. Wartime experiences provided a considerable quantity of damaged equipment which was used as a basis for setting up initial shock-testing requirements. This was an unusual condition and its repetition would be costly and impractical under normal conditions. It should be recognised, however, that information of this type is of utmost importance for validating a shock-testing standard.

Perhaps the problem can be approached in a more hypothetical and analytical manner by comparing the response of an idealised structure, such as the beam in Fig. 1, with both the shock experienced in service and that produced by shock-testing machines. Numerous measurements of shock under service conditions have been and are being made. By analogs or other convenient methods, the response of simple systems of various natural frequencies can be determined for both actual service and shock-testing conditions. When the response spectra for the two conditions coincide, the shock test may then be considered to have a type of equivalence with the shock experienced in service.

One of the difficulties in the way of obtaining a true equivalence of these conditions lies in the many varieties of shock motion experienced in service. There appears to be little basis for selecting one of these shock motions as a reference level for shock-testing machines, to the exclusion of other shock motions. It is perhaps logical to select the one of greatest probable severity. This selection, however, overlooks the cumulative effect of many shocks of different severity. Actual service conditions vary widely, with a consequent variation in the nature and severity of the shock. The shock recurs numerous times at various repetition rates for different degrees of severity.

Any attempt to rationalise the subject of damage experienced as a result of shock must consider the cumulative effect of repetitions of stress. A further study of the cumulative effect of repeated stress ultimately may lead to an adjustment factor which will permit a more rational correlation of repeated shocks with a single shock.

Such a procedure is not entirely without promise for a long-range programme, but there is not at present sufficient information available to form the basis for an immediate solution.

Vibrations of Turbine Blades with Loose Hinge Supports

By F. NIORDSON. (From *Acta Polytechnica*, Mechanical Engineering Series, Vol. 3, No. 3, 1954, 11 pages, 4 illustrations.)

A method of finding the natural frequency of the fundamental bending mode of a turbine blade with a loose hinge support is presented in this article. The equations of motion are derived and some general properties of the solution are discussed, using a minimum principle. The method is illustrated by an example.

THE importance of vibration in determining the life of rotating parts, especially the blades, of steam turbines has long since been recognised. Thus, efforts have been made to find reliable methods of determining the natural frequencies of the blades in the rotating system and of avoiding dangerous resonances with the rotational speed. The benefit of damping has also been recognised and, where vibrations have been considered dangerous, damping has been introduced by abandoning rigid mounting of the blade root in favour of a loose fit.

The fir-tree design of blade root has been shown to have good damping at low and moderate rotational speeds, but at high speeds this damping becomes negligible. The loose-hinge design has shown considerably better damping characteristics. The loose hinge (Fig. 1) operates in a different way from conventional blade roots. When the diameter of the hole is larger than that of the pin, the blade root is made to roll on the pin (which is rigidly connected to the disc) and, if the contact stresses are sufficiently low, so that the material remains in the elastic range, the centrifugal force will not be able to lock the root in a fixed position. Damping is present, owing to the friction between the lips and the faces of the disc, and the centrifugal force does not appreciably affect the tightness of fit between these surfaces.

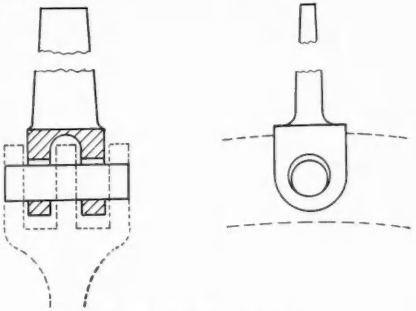


Fig. 1. **Loose hinge support.**

When the blade is mounted rigidly on the disc, it acts as a cantilever beam in bending and when the range of rotational speed is wide, as in jet engines or gas turbines, the blade is usually designed so that the frequency corresponding to the fundamental bending mode is higher than the third or preferably fourth multiple of the maximum rotational speed. Moreover, it is customary to avoid resonance with the number of combustion chambers, if the ducting is not very long and if this resonance does not occur at a low rotational speed, at which the stresses are low.

A blade with a loose hinge is subjected to the centrifugal force which will try to hold the blade in a radial position but, owing to the tangential components of the gas forces, the position of equilibrium is slightly inclined, the angle depending on the ratio between these forces. The fundamental mode of vibration consists of a rigid-body pendulum motion on which a bending motion is superimposed.

EQUATIONS OF MOTION

The blades considered here have an approximately straight neutral axis ; they have principal axes of inertia which are nearly parallel at all sections and have, furthermore, one principal flexural rigidity much smaller than the other. It is therefore reasonable to assume that the neutral axis of the blade in the undeformed state is straight, and that there exists a plane of bending in which the neutral axis will remain while being deformed.

In order to introduce suitable co-ordinate systems, the lines of contact between the blade and the pin in a position of equilibrium are defined. These two lines, L_1 on the blade, and L_2 on the pin, will coincide in a state of equilibrium in which only centrifugal forces act on the blade and no frictional forces exist between the blade and the pin.

Now, let x, y, z be a rectangular co-ordinate system, rigidly connected with the disc, the x-axis in radial direction, the y-axis in tangential direction, and the z-axis coinciding with L_2. In this system the centre of the pin is at $x = r_2, y = 0$. Also, let u, v be a rectangular co-ordinate system in the principal plane of bending, with the origin taken on the line L_1, the u-axis being the neutral axis of the blade in the undeformed state. The angle between the u,v-plane and the x,y-plane is denoted by β, and R denotes the distance between the centre of the disc and the origin of the x, y, z-system.

The position of a point on the neutral axis of the blade with the co-ordinate u is determined from

$$y = \varphi u + v \cos \beta \; ; \; z = -v \sin \beta. \quad . . \qquad (1)$$

Here, only first order terms of φ and v are retained, φ being the angle between the u- and the x-axis and v the deflection in the principal plane of bending. The function $\varphi(t)$ defines the rigid body pendulum motion and $v(u, t)$ is the bending function.

Consider a section of the blade at $u = u_o$. The forces acting in this section on the surface of the top part of the blade are a bending moment $M\,(u_o)$ and a normal force $N(u_o)$. Shear force can be neglected, as it does not enter into this discussion.

If M_y and M_z are the components of the bending moment in y- and z-direction respectively, the resulting bending moment M perpendicular to the principal plane of bending is

$$M = M_z \cos \beta - M_y \sin \beta \quad . . \qquad (2)$$

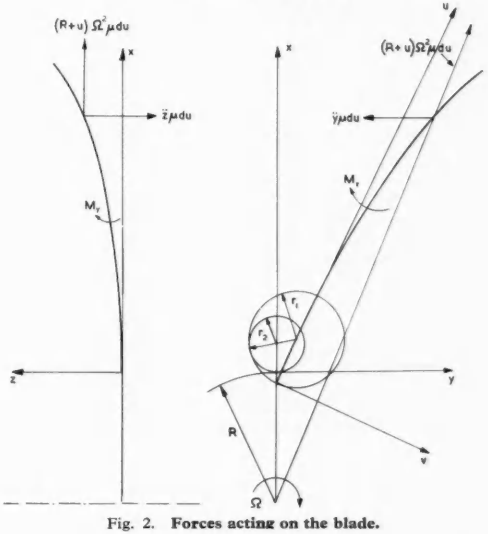


Fig. 2. **Forces acting on the blade.**

The bending moment will, in general, also have a component in the plane of bending ; however, since it has been assumed that the bending takes place only within this plane, that component is of no interest.

From Fig. 2, the components of the bending moment are found to be

$$M_z(u_o) = \int_{u_o}^{l}(u-u_o)\left[(R+u)\,\Omega^2\frac{y}{R+u} - \ddot{y}\right]\mu\,du - \int_{u_o}^{l}(y-y_o)\,(R+u)\,\Omega^2\,\mu\,du \quad .. \quad (3)$$

and

$$M_y(u_o) = -\int_{u_o}^{l}(u-u_o)\,\ddot{z}\,\mu\,du - \int_{u_o}^{l}(z-z_o)\,(R+u)\,\Omega^2\,\mu\,du \quad .. \quad (4)$$

The normal force is

$$N(u_o) = \int_{u_o}^{l}(R+u)\,\Omega^2\,\mu\,du \quad .. \quad (5)$$

where $u = l$ is the top of the blade, Ω = the angular velocity of the disc, and μ = the mass per unit length of the blade.

Partial derivatives with respect to time are indicated by a dot and with respect to u by a dash.

Let $q\,(u,t)$ denote the transversal load per unit length of the blade. The deflection $v\,(u,t)$ will then satisfy the beam equation

$$(EI\,v'')'' = -q \quad .. \quad .. \quad (6)$$

where EI is the flexural rigidity of the blade.

Since $q = M''$, after taking the second derivative of eqs. (3) and (4) with respect to u_o and combining according to eq. (2),

$$-q = (\varphi u + v\cos\beta)\,\Omega^2\,\mu\cos\beta - (\ddot{\varphi}\,u\cos\beta + \ddot{v})\,\mu - (\varphi\cos\beta + v')\,(R+u)\,\Omega^2\,\mu + N\,v'', \quad (7)$$

where u_o has been replaced by u.

Since the fundamental mode will be dealt with, a harmonic solution is sought, of the form

$$\varphi(t) = \phi\sin\omega\,t,\; v(u,t) = V(u)\sin\omega\,t,\; q(u,t) = Q(u)\sin\omega\,t, \quad (8)$$

which, substituted in eq. (7), yields

$$-Q = \omega^2\,\mu\left\{\phi\,u\cos\beta + V + \frac{\Omega^2}{\omega^2}\left[-V\cos^2\beta - V'(R+u) + V''\frac{1}{\mu}\int_{u}^{l}(R+u)\,\mu\,du - \phi\,R\cos\beta\right]\right\} \quad (9)$$

and, instead of eq. (6), we get

$$(EI\,V'')'' = -Q \quad .. \quad .. \quad (10)$$

When the expression (9) is inserted into eq. (10) a differential equation of fourth order for the function V, in which ϕ occurs as a parameter, is obtained. However, ϕ is dependent on V, and the relation between them is obtained by a consideration of the equilibrium. The moment of all forces acting on the blade with respect to the instantaneous line of contact is zero, or

$$\int_{o}^{l}[(y+r_2\,\gamma)\,(R+u) - uy]\,\Omega^2\,\mu\,du + \int_{o}^{l}\ddot{u}y\,\mu\,du = 0, \quad (11)$$

where γ denotes the angle of rolling.

Using eqs. (1) and (8) and introducing the condition of rolling,

$$\gamma = \frac{r_1}{r_1 - r_2}\,\varphi = c\,\varphi \quad .. \quad .. \quad (12)$$

we obtain

$$\phi\,J\left(1 - k^2\frac{\Omega^2}{\omega^2}\right) + \int_{o}^{l}\left(u - \frac{\Omega^2}{\omega^2}R\right)V\cos\beta\,\mu\,du = 0 \quad (13)$$

in which

$$k^2 = \frac{M\,R\,h}{J}\left(1 + c\,r_2\,\frac{R+h}{Rh}\right) \quad .. \quad (14)$$

where J = total moment of inertia of the blade with respect to L_1, M = the total mass of the blade, and h = the u-coordinate of the centroid.

The function V and the number ϕ have to satisfy the system of eqs. (10) and (13), and V must also satisfy the boundary conditions

$$V(0) = V'(0) = V''(l) = (EI\,V'')'(l) = 0 \quad (15)$$

This system of equations is linear and homogeneous in V and ϕ, ω^2 being the eigenvalue.

PROPERTIES OF THE SOLUTION

In order to study the properties of the solution, it is suitable to introduce the energy of the system.

At the time $t = 0$, the kinetic energy of the blade, referred to the x, y, z-system, is

$$T = \frac{1}{2}\,\omega^2\int_{o}^{l}(\phi\,u + V)^2\,\mu\,du = \omega^2\,T^{\star} \quad .. \quad (16)$$

In this section, β is put equal to zero for the sake of simplicity. When $\beta \neq 0$, an analogous reasoning may be used.

At $t = \pi/2\,\omega$, at which time the velocity of every point of the blade is zero, the energy consists of two parts. One is the potential energy the blade has accumulated in the field of the centrifugal forces,

$$W_1 = \int_{o}^{l}\left[(cr_2 + u)\frac{\phi^2}{2} + \phi\,V + \frac{1}{2}\int_{o}^{u}(V')^2\,du - \frac{1}{2}\frac{(\phi\,u + V)^2}{R+u}\right](R+u)\,\Omega^2\,\mu\,du = \Omega^2\,W_1^{\star}, \quad (17)$$

where the quantity in the square brackets is the radial displacement of an element of the blade with the co-ordinate u. The other part is the elastic energy accumulated in the blade during bending,

$$W_2 = \frac{1}{2}\int_{o}^{l}(V'')^2\,EI\,du \quad .. \quad .. \quad (18)$$

Since $T = W_1 + W_2$, we get, solving for ω^2,

$$\omega^2 = \frac{\Omega^2\,W_1^{\star} + W_2}{T^{\star}} \quad .. \quad .. \quad (19)$$

The eigenvalue ω^2 is determined from eq. (19) when the (as yet unknown) eigenfunctions V and ϕ are inserted.

Using the minimum principle of elasto-kinetics,

$$\omega^2 = \underset{\phi,\,V}{\text{Min}}\;\frac{\Omega^2\,W_1^{\star}(\phi,V) + W_2(V)}{T^{\star}(\phi,V)} \quad .. \quad (20)$$

where ϕ is any real number and V any admissible

function, i.e., a function which is twice differentiable and satisfies the essential boundary conditions $V(0) = V'(0) = 0$, $V \equiv \phi = 0$ being excluded.

Consider first the case of an absolutely rigid blade. For such a blade $V \equiv 0$, and from eq. (19), integrating eqs. (16) and (17),

$$\omega^2 = k^2 \Omega^2 \quad .. \quad .. \quad (21)$$

and the same result follows from eq. (13). For a rigid blade the natural frequency is thus proportional to the rotational speed, $\omega_r = k \Omega$.

Since the domain of admissible functions ϕ, V contains all functions ϕ, 0, it follows from eq. (20) that

$$\omega < \omega_r \quad .. \quad .. \quad .. \quad (22)$$

Secondly, consider a blade with finite flexural rigidity, but rigidly mounted at the root. For such a blade, $\phi = 0$, and similarly it can be concluded that

$$\omega < \omega_f, \quad .. \quad .. \quad .. \quad (23)$$

where ω_f denotes the natural frequency of the fundamental bending mode of the fixed end blade.

Thirdly, consider a blade with negligible flexural rigidity, i.e., $EI = 0$. For such a blade, which acts as an ideal chain, $W_2 = 0$, and

$$\omega_c^2 = \Omega^2 \operatorname*{Min}_{\phi,\, V} \frac{W_1(\phi, V)}{T(\phi, V)} = k_0^2 \Omega^2, \quad .. \quad (24)$$

where k_0^2 is a positive constant †. Since, for a real blade with finite flexural rigidity, $W_2 > 0$, it follows that

$$\omega \geq \omega_c \quad .. \quad .. \quad (25)$$

and obviously $k_0 \leq k$.

It will now be shown that the minimising value of ϕ is zero in eq. (24).

Let $\phi^\star$ and $V^\star$ be the minimising functions of (24) and let $U = \phi^\star u + V^\star$. Then, from eq. (16),

$$T = \frac{1}{2}\int_o^l U^2 \mu \, du \quad .. \quad .. \quad (26)$$

and from eq. (17),

$$W_1^\star = \int_o^l \left[c r_2 \frac{\phi^{\star 2}}{2} - \frac{1}{2}\frac{U^2}{R+u} + \frac{1}{2}\int_o^u (U')^2 \, du) \right] (R+u)\mu \, du \quad .. \quad (27)$$

The number k_0^2 is equal to the minimum of the quotient $W_1^\star(\phi, U)/T^\star(U)$ for all admissible functions U and ϕ, since the domain of U is identical with that of V. Furthermore, since the integral $\int_o^l (R+u)\mu \, du > 0$ the minimising value of ϕ must be $\phi^\star = 0$. Hence,

$$k_0^2 = \operatorname*{Min}_V \frac{\int_o^l (R+u)\mu \int_o^u (V')^2 \, du \, du}{\int_o^l V^2 \, du} - 1 \quad (28)$$

From eqs. (20), (24) and the inequality (23) it follows that $\omega_f \to \omega \to k_0 \Omega$ as $\Omega \to \infty$, which means that $k_0 \Omega$ is an asymptote for the curves $\omega_f(\Omega)$ and $\omega(\Omega)$.

†The boundary condition $V'(0) = 0$ is relaxed in this case and the functions V may be chosen among a larger class. This is due to the fact that the differential equation for V has been reduced to a second order equation, since $EI = 0$. This is also clear from a mechanical point of view.

Solution by Successive Approximations

In order to find the natural frequency of any given blade, the system of eqs. (10) and (13), with consideration of the boundary conditions (15), must be solved. Exact solutions are practically excluded; however, the system may be solved by successive approximations. This may be done with a modification of the Vianello-Stodola method.

To apply this method, it is essential that the lateral load of Q of the beam be proportional to a function of ω and not dependent on ω in any other way. In the present case, however, ω appears in a more complicated way, as is seen from eq. (9), where it must be observed that ϕ is also dependent on ω. Nevertheless, the Vianello-Stodola method may be used in this case.

Solving eq. (13) for ϕ and substituting into eq. (9) yields Q as ω^2 times an operator F on V and the ratio ω/Ω, i.e.,

$$-(EI\, V'')'' = \omega^2 F(V, \omega/\Omega).$$

F depends also on the function μ and other parameters, which are considered as being fixed.

However, by considering the ratio of ω/Ω as being fixed at any value between the limits k_o and k, the equation will then appear in a form suitable for the application of the Vianello-Stodola method. The function V and the eigenvalue ω^2 are found by successive approximations, starting out with any (preferably simple) non-trivial function V.

Repeating the process for different values of the ratio ω/Ω, ω may be constructed as a function of ω/Ω with any desired accuracy. The result, ω as a function of Ω, is then easily obtained.

The solution for a rigidly fixed blade can be obtained in a similar way by putting $\phi = 0$ in eq. (9) and neglecting eq. (13). Since V generally converges rapidly, the method is not too tedious, but still requires a considerable amount of work.

The number k_o can also be obtained by successive approximations. For $EI \equiv 0$, also $Q \equiv 0$, and since $\phi = 0$, as already found, eq. (9) yields the following second order differential equation for V:—

$$k_0^2 V + V - V'(R+u) + V'' \frac{1}{\mu}\int_u^l (R+u)\mu \, du = 0 \quad (29)$$

which can be written

$$\left[\int_u^l (R+u)\mu \, du \, V'\right]' = -(k_0^2 + 1)\mu V. \quad (30)$$

The function V must also satisfy the boundary conditions

$$V(0) = 0 \text{ and } V'(l) = (k_0^2 + 1)\frac{V(l)}{R+l} \quad (31)$$

the second giving an expression for the condition that the tangent at the top of the blade has the direction of the resulting force at that point.

Integration of eq. (30) yields, when the boundary conditions eq. (31) are taken into account.

$$V = (k_0^2 + 1)\int_o^u \frac{\int_u^l V \mu \, du}{\int_u^l (R+u)\mu \, du} \, du \quad .. \quad (32)$$

In this form, the equation is suitable for numerical

computations. Starting out with any function V that satisfies $V(0) = 0$ and substituting into the right-hand member of eq. (32), a second approximation is obtained. Repeating the process, any degree of accuracy in V may be obtained, and the eigenvalue k_0^2 is then easily determined.

EXAMPLE

A blade, with the dimensions shown in Fig. 3, has a rectangular cross-section with $\beta = 0$ for the sake of simplicity, but the mass distribution is equal to that of an actual blade. Owing to the relatively small flexural rigidity of the blade in this example, in comparison with a real blade of corresponding length, the influence of the finite flexural rigidity will be better illustrated.

Fig. 3. **Experimental blade.**

On the assumption that the blade is made of a steel with a density of $7{\cdot}8 \times 10^{-6}$ kg/mm³, it will be found that

$$h = 130 \text{ mm}, \quad M = 2{\cdot}28 \text{ kg}, \quad J = 68{,}700 \text{ kg mm}^2$$

With $R = 475$ mm, $r_1 = 17$ mm, $r_2 = 15$ mm, we obtain

$$c = 8{\cdot}5 \text{ and } k = 2{\cdot}14.$$

If the blade were rigid, then $\omega = 2{\cdot}14\ \Omega$, and this will also hold for the actual blade, when Ω is sufficiently small.

The blade is divided into 11 parts between $u = 0$ and $u = 370$, the first section at $u = 40$ and the other sections with a distance of 33 mm. The co-ordinate of the ith element to its centre is denoted by u_i, its mass by $\mu_i \Delta_i$, and the moment of inertia at u_i by I_i.

The first ratio ω/Ω for which ω was computed was put equal to 2, i.e., slightly less than k. The first guess for the function V was

$V_i^0 = 0, 0{\cdot}22, 0{\cdot}64, 1{\cdot}20, 1{\cdot}49, 1{\cdot}68, 1{\cdot}80, 1{\cdot}88, 1{\cdot}94, 1{\cdot}98, 2{\cdot}00$

for $i = 1, \ldots, 11$ respectively.

From eq. (13), ϕ was computed by numerical integration and was found to be $\phi^0 = 0{\cdot}0217$.

The derivatives V' and V'' were computed with the approximate formulae

$$V_i' = (V_{i+1} - V_{i-1})/2\,\Delta_i$$

and

$$V_i'' = (V_{i-1} - 2\,V_i + V_{i+1})/\Delta_i^2$$

and the load Q_i^0 could then be computed from eq. (9), where the integral was replaced by the corresponding finite sum. Then, the next approximation V_i^{I} was found by integrating the load four times numerically, according to the Vianello-Stodola method. The arithmetic mean value of the ratios Vi^{I}/Vi^0 was found to be $0{\cdot}135 \times 10^{-6}\ \omega^2$, with great differences between the individual ratios. The value used for Young's modulus was $E = 21{,}000$ kg/mm². This process was then repeated twice.

The result was

Mean value of $(V_i^{\text{I}}/V_i^0) = 0{\cdot}135 \times 10^{-6}\ \omega^2$
" " " $(V_i^{\text{II}}/V_i^{\text{I}}) = 6{\cdot}10 \times 10^{-6}\ \omega^2$
" " " $(V_i^{\text{III}}/V_i^{\text{II}}) = 5{\cdot}87 \times 10^{-6}\ \omega^2$

and the process was interrupted at this point, since the individual differences were below 5%, the error of the mean value being less.

Choosing now the ratio $\omega/\Omega = 1{\cdot}9$ and using V_i^{III} from the preceding computation as a first approximation V_i^0 for V_i in this case, the convergence is rapid. Thus, the mean value of the ratios V_i^{I}/V_i^0 was found to be $2{\cdot}91 \times 10^{-6}\ \omega^2$, with the greatest individual difference of less than 1%.

The computation of ω was also made for the ratios ω/Ω of 1·8 and 1·7, yielding the following result :—

ω/Ω	ω	Ω
2	413	206·5
1·9	586	309
1·8	752	418
1·7	1018	599

For the same blade, with a rigidly mounted root, the following values were obtained :—

ω/Ω	ω	Ω
∞	625	0
2·5	786	314
2·0	964	482
1·8	1181	656

The asymptotic value k_0 was computed with successive approximations, according to eq. (32), where the integrals were replaced by finite sums, and was found to be

$$k_0 = 1{\cdot}38.$$

The function V converged very rapidly in this case.

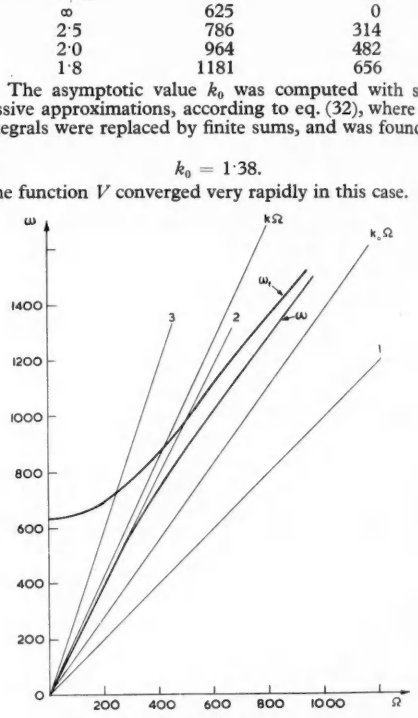


Fig. 4. **Resulting frequency.**

ω_f Rigidly fixed blade.
ω Actual blade with loose hinge support.
$k\Omega$ Rigid blade with loose hinge support.
$k_0\Omega$ Blade with $EI = 0$.

Fig. 4 shows the result in a diagram. The only resonance of the blade with the loose hinge support is at $\Omega = 206{\cdot}5$ with the second multiple of the rotational speed, while the fixed end blade will be in resonance with all multiples excepting the first. This shows clearly an advantage for the loose-hinge type of support. Had k been less than 2, no resonance could occur with the rotational speed. This blade can be obtained by decreasing cr_2 ; if, for instance, r_2 is taken as less than 14·5 mm, k will be less than 2. The theoretical minimum of k is determined by $k = M\,R\,h/J = 1{\cdot}43$. The natural frequency ω of the fundamental bending mode would then be between the narrow limits $1{\cdot}38\Omega$ and $1{\cdot}43\Omega$. In reality however, the minimum value of k cannot be obtained, owing to the contact stresses between the pin and the hole, which will limit the designer in the choice of cr_2.

Recording of Transient Phenomena in Machine Tools

By S. AMARI. (From *Macchine*, Vol. 9, No. 5, May 1954, pp. 467-473, 4 illustrations.)

The operation of machine tools is frequently disturbed by transient phenomena which require detailed investigation in order to determine their causes and character. The present article describes a new method of point-by-point recording which requires comparatively little equipment and which gives direct recordings on paper sheets.

THE discontinuous recording of variable quantities by means of points can be carried out in two different ways :—(1) The deviations of the output variable from its reference value, or normal variation, can be recorded over a certain period of time, as functions of changes in governing parameters, and (2) the output quantity can be varied over a range of predetermined values, and the corresponding variations of its parameters recorded. In both cases, the point-by-point recording should be sufficiently detailed to indicate instantaneous variations in frequency and amplitude which may not be directly observable under working conditions. The sensitivity of the indication is dependent, therefore, on the number of recorded points obtained per second, and their size relative to the magnitude of the variable being studied. The recordings, being based on constant time intervals, indicate changes in the magnitude of the disturbances as functions of the time elapsed. An acceleration is indicated by a shorter distance than normal, and a deceleration by a longer distance, between two successive points on the recording paper.

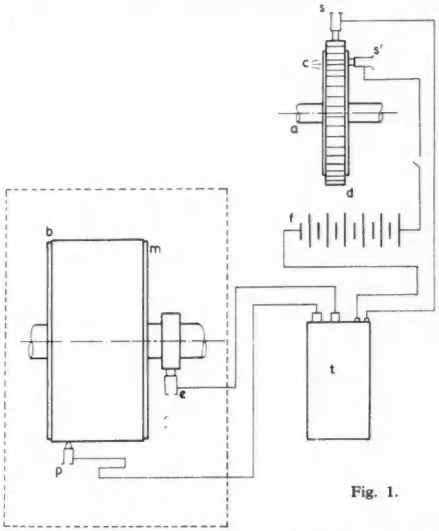


Fig. 1.

The recordings described in the following were obtained from three different types of machine tools, i.e., a universal milling machine, a shaping machine, and a milling-cutter grinding machine. Fig. 1 shows the schematic arrangement of the equipment for the universal milling machine. The spindle (*a*), carrying the cutter, is provided with a light disc (*d*) of electrically insulating material, in which a series of metal strips (*c*) is rigidly mounted radially and equally spaced around the periphery. The inner ends of the strips are electrically connected. When disc (*d*) is rotated, each strip in turn briefly closes an electric circuit *via* contacts (*s*) and (*s'*). There is a corresponding instantaneous flow of current, supplied from a battery (*f*), into the primary of a transformer (*t*), whose secondary acts on stylus (*p*), which records a point on a sheet of paper (*b*) rolled around a cylinder (*m*). This cylinder is rotated at a constant speed, while the stylus travels uniformly in a direction parallel to the axis of the cylinder ; the width of the trace, i.e., the period between two returning motions of the stylus, is, however, adjustable. Thus, successive points are situated on a portion of a helix, while the peripheral spacing depends on the time elapsed between the passage of one strip and the next over the contacts. In this way, a deceleration is indicated by an increase in the " pitch " between two points, whereas an acceleration is shown by a reduction. To obtain ample sensitivity, a new recording method was evolved, making it possible to operate without instrumental error at more than 1500 points per second.

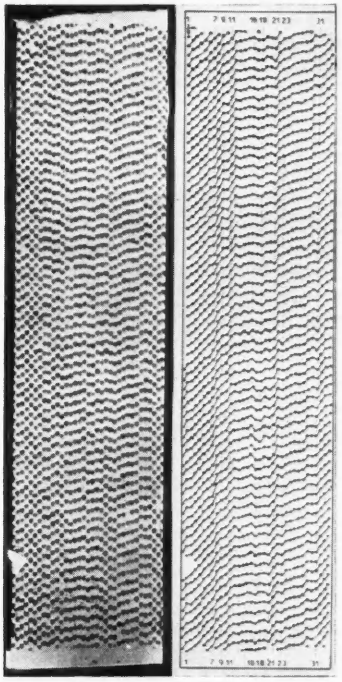


Fig. 2.

(a) (b)

Fig. 2(a) shows a reduced photograph of a recording taken on the milling machine, while it was machining a groove of trapezoidal cross-section into a homogeneous workpiece. The feed rate was 30 metres per minute, corresponding to 0·2 mm per revolution. The recording is shown as a flat sheet after removing the paper from the recording cylinder. The various spirals formed by the recording points end at the right-hand edge of the paper and appear as a set of parallel, equidistant lines with varying slope, giving a wavy pattern. This recording can be analysed as shown below.

It is convenient to denote as " columns " the lines of points in the vertical direction, and to describe as " rows " the lines of varying shape formed by consecutive recording points situated in different columns. Furthermore, each row of points can be denoted by an identification number. When the rotational speed of

the milling machine is constant, the recording points are all equally spaced, and the rows are equidistant, parallel straight lines, with a slope angle depending on the angular phase shift (on the recording cylinder) between consecutive points of the same identification number. When deceleration or acceleration occurs, the pitch is correspondingly modified and the slope of the rows shows variations which in themselves are a clear indication of the duration and magnitude of the transient phenomenon, although the latter can be accurately determined quantitatively from the pitch variations. The rate of recording should be such as to suit the requirements of the analysis. In the present example, there are 42 recording points per revolution of the milling tool (or 3·5 points per tooth), corresponding to a rate of 107·1 recording points per second.

Fig. 2(b) is a print from this recording, which has been divided into ten groups of columns, here designated (a) to (j). The first group is typical of no-load conditions. Further on, as the milling cutter proceeds to remove metal, there are marked variations in pitch, indicating decelerations and accelerations of considerable magnitude. Analysis of these groups reveals the following details :—

(a) Columns 1-7 : Idling conditions with small disturbances, presumably due to torsional vibrations of the spindle carrying the milling cutter (caused by the belt joint), slight shaft misalignment, variable resistance of the bearings owing to small momentary defects in lubrication, etc. These are visible because of the sensitivity of the indication method, but otherwise the rows of these first columns are parallel straight lines, corresponding to a constant speed of rotation of the cutter.

(b) Column 7 : Pitch variation and distortion of the rows, due to actuation of the clutch for the operation of the work-table.

(c) Columns 8 and 9 : Slight deceleration, due to the additional load on the drive, as the workpiece approaches the cutter, with small, sudden disturbances, caused by initial defects in lubrication and take-up of play.

(d) Columns 9-11 : First contact of the milling cutter with the work, apparent as a sudden deceleration, followed by a rapid acceleration. The latter is due partly to the elasticity of the spindle carrying the cutter and partly to the taking-up of play in the table drive, while the spindle momentarily returns to its no-load speed.

(e) Columns 11-16 : A marked deceleration of spindle speed is noticeable, as the cutter again comes into contact with the work, with irregularities due to scraping of the teeth against the work, braking during removal of metal, followed by sudden release of the load after loss of contact, with torsional vibration of the spindle, momentary instability of the forces involved, accompanied by vibrations of the workpiece, as well as other effects, already listed under (a).

(f) Columns 17 and 18 : Deceleration is clearly noticeable. The recording points have a different pattern, because 3·5 of these correspond to the angle between two successive teeth of the cutter and several teeth are removing metal simultaneously ; the reduction in speed is therefore appreciable.

(g) Columns 19-21 : Irregular accelerations up to the idling speed occur between periods of operation at reduced speed, some of which are comparable in magnitude with those under (f). This indicates that cutting action is discontinuous. For the removal of metal, there must be sufficient pressure between the cutter and the work, and this pressure is developed gradually until cutting occurs ; it then diminishes until the workpiece has moved further towards the cutter.

(h) Column 22 : The pitch is considerably reduced, indicating a sudden and pronounced acceleration. This is due to the elasticity of the cutter after the removal of metal, with slight or no contact between cutter and work, so that the speed tends to rise to its no-load value.

(i) Columns 23-31 : Irregular conditions, due to cutting action, scraping, and final metal removal.

(j) Columns 31-34 : Resumption of idling-speed conditions, with repetition of the small disturbances previously described.

The investigation on the shaping machine was made during the machining of a homogeneous workpiece, 180 mm in length, the total stroke of the tool slide being 220 mm. Fig. 3(a) is a reduced photograph of the recording taken during this work. This recording indicates all the variations in the translatory speed of the tool slide, which has a reciprocating motion, with mean velocities of 5·6 and 8·4 metres per minute during the working stroke and the return stroke, respectively. The recording equipment was similar to that shown in Fig. 1, but was so arranged as to obtain a recording point for each displacement of 0·7 mm of the slide. In this instance, the object was to investigate the functioning of the reversing arrangement used, which was suspected to be the cause of abnormal variations in the motion of the tool slide. It was found that operation of the clutch at times absorbed considerable energy, intermittently producing appreciable reductions in speed, whereas at other times there was evidence of slip. A print from the recording is reproduced in Fig. 3(b), in which some of the particularly irregular phases are marked in the corresponding columns. It was not possible to mark all the rows continuously, because of the appreciable variations in pitch, particularly in the neighbourhood of the reversals. The following details can, however, be pointed out :—

(a) Columns 1 and 2 : These columns correspond to the end of a working stroke, at zero load ; the tool is not yet in contact with the work, the feed being intentionally interrupted. On starting, there is an appreciable deceleration, due to the abnormal resistance of the clutch control mechanism, which is automatically operated at the end of each stroke by the tool slide. After overcoming this resistance, there is a rapid acceleration, followed by constant speed.

(b) Column 3 : Deceleration and acceleration, corresponding to the reversal of motion of the tool slide.

(c) Columns 4-8 : After acceleration, the return motion takes place at constant speed.

(d) Column 9 : The clutch operates without abnormal resistance, so that the reversal occurs normally.

(e) Columns 10-19 : Gradual running up to speed, with a slight slipping action (apparent in column 11). During this period, the tool contacts the workpiece after the feed mechanism has been put into operation, and this results in a sudden deceleration as the tool begins to remove metal (see column 15) ; motion is somewhat irregular, owing to slight slip caused by the defective clutch.

(f) Columns 20-22 : Irregular reversing, with a strong initial resistance due to the control mechanism of the clutch, causing an initial sudden deceleration, with subsequent imperfect engagement of the friction clutch, which operates during the reversing phase.

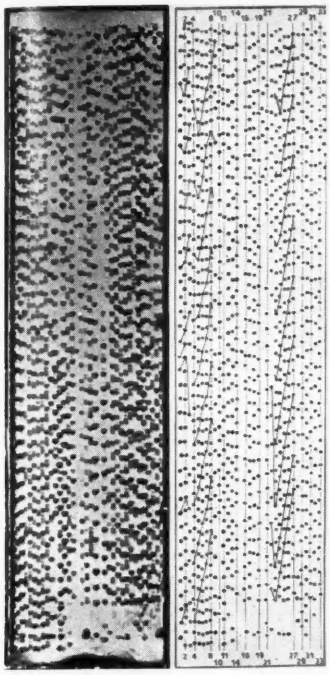
(g) Columns 23-27 : After a slow and irregular acceleration, the slide completes its return stroke at nearly constant speed.

(h) Column 28 : Reversal occurring in a regular manner.

(i) Columns 29-33 : The working stroke proceeds normally, apart from noticeable decelerations, visible in column 32. These could be due to unexpected obstructions encountered by the tool in removing metal, vibrations, elastic springback of various components, or slipping of the friction cone. The latter possibility seems most probable, in view of the previous results, which show little evidence of other causes.

The above example also indicates possible uses of the point-by-point method in acceptance tests of machine tools for a final check of operating conditions.

The investigation of the milling-cutter grinding

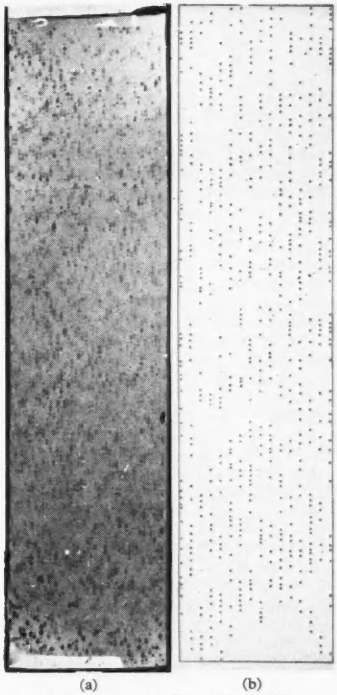


(a) (b)

Fig. 3.

machine is of interest because it revealed a type of trouble which is not generally taken into account in machines of this type, i.e., torsional vibration of the drive spindle of the grinding wheel. The latter, in the machine under examination, is keyed to one end of this spindle, which has two supports, one near the wheel and the other at the opposite end, whereas the drive pulley is keyed between these two supports. The tests were carried out to verify whether the point-recording method is suitable for the study of transients of very brief duration, for which it is necessary to take a very large number of points per second, and also to investigate the effects of the elasticity of the driving elements on the operation of the grinding wheel. In the view of the author, these effects, which occur in certain rough-machining operations, are by no means negligible.

In this instance, an analysis was made of the running speed of the grinding wheel under no-load conditions. The wheel, with a diameter of 200 mm, operated at 1550 rpm, corresponding to a peripheral speed of 16·2 m/sec. The recordings were taken at a rate of 72 recording points per revolution of the grinding wheel, or 1870 points per second. In the absence of disturbances, it was thus necessary to obtain recording points with a constant pitch of 3·1 mm, assuming that the method would permit recordings to be taken at such a high speed. In this respect, results were satisfactory and showed that the method was still efficient. It was found, however, that the recorded points were grouped together, indicating the presence of an irregularity in the motion of the wheel. The recorded points appeared in groups of 10 to 15, over the distance corresponding to the theoretical pitch, but with an irregular distribution. This is clearly visible in the reduced photograph of the recording, shown in Fig. 4a. The points are of a smaller size than those in the previous tests, since it was necessary to obtain a sufficiently large number on the recording sheet, in order to cover a long enough running period. A print from this recording, reproduced on a



(a) (b)

Fig. 4.

slightly larger scale, is shown in Fig. 4(b). The groups of points are clearly visible and indicate that the wheel, besides having a normal rotary motion, also has an oscillatory motion due to torsional vibration of the spindle. It is considered probable that conditions of this type also occur as a result of the influence of the work itself, so that further recordings of the transient behaviour should again provide useful information.

It should be mentioned that all the investigations described were qualitative rather than quantitative, because uncertainty in the size of the recording points sets a limit to the measuring accuracy of pitch variations. However, it is possible to obtain accurate quantitative measurements. Reverting to Fig. 1, it can be seen that there is a sliding contact (*e*) connected to the secondary of the transformer (*t*). The other terminal of the transformer secondary is connected to a metal point (*p*), instead of a stylus. During the rotation of the cylinder, whenever there is a voltage pulse across the secondary of (*t*), a spark discharge occurs at point (*p*), and the spark perforates the strip of paper (*b*), leaving a small hole with a diameter of about one-hundredth of a millimetre. It is therefore possible to make quantitative evaluations of considerable accuracy, even with very brief and rapidly varying transient phenomena.

To obtain minute perforations of this kind, considerable research was necessary. It was found that photographic paper was most suitable for this purpose, owing to the dielectric quality of its sensitised surface. The recordings are taken in broad daylight, with the photographic paper strip rolled around the cylinder, and the sparks perforate this paper each time a point is recorded. Each perforation is the centre of a small black spot, which is clearly visible to the naked eye (whereas the perforation itself is not), but the spot appears only some time after the recording has been made. Although these spots were an unexpected result, they were found useful, since they made possible a rapid qualitative inspection of the recordings.

(*Concluded on page* 368)

Brazing and Grinding of Carbide-Tipped Tools

By L. Fine. *

Most of the troubles experienced when using carbide-tipped tools stem from bad brazing or poor grinding. Assuming adequate servicing, even an inferior grade of carbide will give reasonable results in many cases, but full value cannot be obtained from any grade of carbide, however good, unless it is soundly brazed and properly sharpened.

BRAZING.

Brazing is the most widely used method of attaching carbide tips to their shanks. It is cheap, quick, convenient, and neat. Given careful supervision, it can be carried out on a mass-production basis with semi-skilled labour. Unfortunately, it is not possible to state from exterior appearance alone that a tip is firmly brazed, because hidden faults may be present. A further disadvantage is that brazing sets up stresses in the carbide.

Brazing stresses in the carbide tip are caused by the difference in the contraction rates of steel and carbide. At brazing temperatures, the steel tip seat and carbide tip have identical lengths within their area of contact. During cooling, the steel shank contracts between two and three times as much as the carbide, thus bowing the carbide tip and imposing tensile stresses on the top surface. When in this state, carbide probably gives less than its full value. A common technique used to overcome these difficulties is to braze with a thin sandwich of brazing material inserted between tip and shank on all mating faces.

There are several very good brazing alloys. Those having low melting point are used for general applications. Copper and other alloys with a high melting point are used where large quantities of heat may be generated or where a cushioning effect is necessary to enable tips to withstand heavy and sudden loads. On most standard tools the depth of steel under the tip is three times the tip thickness. Young's modulus for carbide is approximately three times that for steel and thus deflections under load are similar in both steel and carbide. It is good practice to braze with copper when this ratio is not adhered to, in order to minimise stresses caused by unequal deflections in the steel and the carbide.

Cleanliness and purity are of great importance in all carbide brazing operations, particularly so when copper or some other alloy with a high melting point is used as the brazing material. Small impurities in the steel will, at high temperatures, foul the mating surfaces and spoil the braze. The highest standards of purity are necessary to achieve a sound copper braze. An oxygen content in the copper of less than 0·01% has been known to have a markedly deleterious effect. All other things being equal, electrolytic copper of the highest commercial standards will give consistently good results in service.

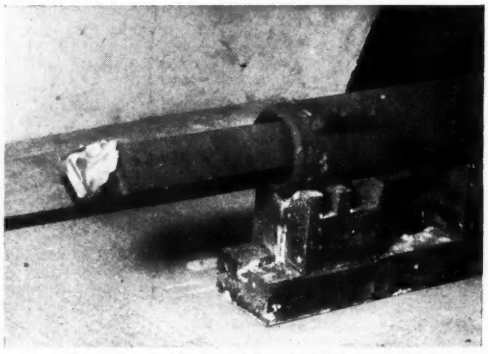


Fig. 1. **Tip, shank, flux, and brazing foil, assembled and mounted in jig, ready for brazing.**

When preparing for the actual brazing operation, all parts should be thoroughly cleaned, de-greased, and left to dry naturally or in a clean air blast. Flux should be applied to the tip seat, the tip, and the piece of brazing foil, and all should be assembled. Both the carbide and brazing foil should project slightly beyond the end of the shank (Fig. 1), in order to minimise the amount of grinding.

Heating is usually carried out by using an oxygen-gas blowpipe where quantities are small, or an induction-heating unit where quantities justify the use of mass-production techniques. Furnace heating is now less used for general brazing than was common some years ago. Instead, furnace heating is sometimes used where brazing is combined with heat treatment of the steel under rigorously controlled conditions. In circumstances such as these, the brazing temperatures must be very carefully "matched" with the hardening temperatures of the steel. Air- or oil-hardening steels are almost invariably used for such purposes, and it is often necessary to design around the need for a sound braze, free from cracks in the carbide tip.

Techniques will change slightly, according to the type of heating used. The basic principles, however, do not materially differ.

Fig. 2. **Application of heat to underside of shank.**

When using a blow torch, heat is first applied to the underside of the shank some little distance away from the nose of the tool (Fig. 2); the heat spreads towards the nose of the tool and the torch is gently moved in order to spread the heat in a uniform manner, till both the tip seat and a considerable portion of the shank are at the melting point of the brazing foil. When all the visible brazing foil has been melted, heat is applied directly to the tip (Fig. 3), until small quantities of molten brazing metal work through the joints and appear on the surface of the tool. At this stage, the tip is "wiped home" or "tapped home" with a rod or stout wire, to release any bubbles of flux which may be trapped in the joint. After removing the torch, the tip is held lightly, yet firmly, in place, with the same rod which was used to wipe home the joint, until the colour of the shank indicates that the temperature has fallen below the melting point of the brazing material. The tool is then immediately plunged

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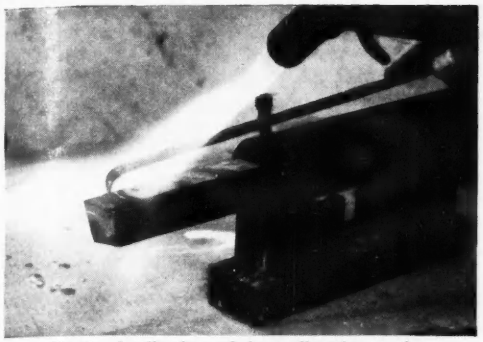


Fig. 3. **Application of heat directly to tip.**

into heated sand, spent charcoal, or some other heat-insulating material, where slow cooling occurs till the tool reaches room temperature. Heat is conducted to the tip seat from the hot portion of the shank, helping to maintain a slow and even rate of cooling, thereby minimising stresses in the carbide. A substantially cold shank would have the effect of conducting heat away from the tip seat, thus accelerating cooling and possibly causing severe stresses in the carbide.

GRINDING AND LAPPING.

Every cutting tool needs sharpening at more or less frequent intervals. The manner in which a carbide-tipped tool is sharpened and the degree of care used will exert a profound influence on performance.

A properly sharpened tool has a good surface finish on its clearance and rake faces, and its shape and angles are the result of design specifications. Conventional techniques to-day are such that the tool shape and angles are obtained by grinding, while the surface finish required is obtained by lapping or by fine-grinding techniques. A tool is ready for servicing when there is a wear land approximately $\frac{1}{32}$ in. wide on the clearance face of the tool. Greater wear will result in increased power consumption and wastage of carbide during sharpening; there is also the risk that the tip may suffer serious damage. When the wear land is only $\frac{1}{32}$ in. wide, the tool shape has not been greatly affected, and for new tools only the following operations are necessary :—

(A) Lap either the rake face or the chip-breaker groove, if this is present.
(B) Lap the clearance faces (Fig. 4).
(C) Hand-hone the cutting edge and, where applicable, the top edge of the chip-breaker groove. This technique removes only a small amount of carbide, and wastage is reduced to a minimum.

The " lapping line " need be only a short distance down the clearance face of the carbide. After lapping a few times, the lapping line will be at the base of the tip. Further lapping at this point would load and glaze the lap, heat the tool, and waste time. The correct technique is the same as that used for grinding a tool which has craters or slight nicks, caused perhaps by overlong use or by being used on material containing hard spots or other damaging inclusions. The recommended procedure is (see Table I) :—

(1) Grind back the steel shank. Do not grind carbide with the same wheel.
(2) Rough-grind the rake face. Remove as little material as possible, consistent with obtaining the designed shape and a reasonable finish.

Operation (2) can be omitted in the case of a tool which requires only its wear-land to be removed and where there is a chip-breaker.

(3) Grind the clearance and plan angles to design specification. Do not grind the steel shank with the same wheel. If shank grinding is necessary, revert to operation (1).
(4) Lap either the rake face or the chip-breaker groove, if this is present.
(5) Lap the clearance faces.
(6) Hand-hone the cutting edge.

Conventional grinding wheels for servicing carbide-tipped tools are of two types, i.e., aluminium-oxide wheels, suitable for grinding steel, and silicon-car-

OPERATION	TABLE SETTING	GRINDING WHEEL				REMARKS
		TYPE	GRIT SIZE	GRADE	STRUCTURE AND CONCENTRATION	
ROUGH-GRIND SHANK	12°–15°	ALUMINIUM OXIDE	24 to 60	J-O	5-8	NEVER GRIND CARBIDE WITH THIS WHEEL
ROUGH-GRIND RAKE ANGLES		SILICON CARBIDE	50 to 100	H-J	5-8	RAKE ANGLES TO SUIT MATERIAL
ROUGH-GRIND TIP CLEARANCE	8°–10°	SILICON CARBIDE	50 to 100	H-J	5-8	
LAP RAKE ANGLES		DIAMOND WHEEL	150 to 220	METAL BONDED	50–100	RAKE ANGLES TO SUIT MATERIAL
OR						
LAP CHIP-BREAKER GROOVE		DIAMOND WHEEL	150 to 220	METAL BONDED	100	CHIP-BREAKER SIZES TO SUIT CUT
LAP TIP CLEARANCE	3°–7°	DIAMOND WHEEL	150 to 220	METAL BONDED	50-100	
HONE EDGE		DIAMOND HONE	150 to 320			MOST IMPORTANT ON HEAVY-DUTY TOOLS
		SILICON-CARBIDE HONE	150 to 220			

THESE OPERATIONS WHERE ONLY TOUCHING UP IS REQUIRED

Table I

bide wheels suitable for grinding the carbide cutting tips. Aluminium-oxide wheels are made up of a fairly tough material having a strong bond. The cutting medium is not hard enough to grind carbide effectively. These wheels quickly dull on carbide, and the bond is so strong that the dull grains remain in place, causing heat checks and cracking of the carbide tip. Silicon-carbide wheels have a hard grain with a rather weak bond. When dulled, the bond allows the grain to be torn out, presenting new sharp cutting edges.

On steel, silicon-carbide grinding wheels are inefficient and wasteful. The action of these wheels on carbide is such that individual grains produce a deep narrow groove. Light is reflected from the side of these grooves, and the result appears to be a very smooth surface. In actual fact, the surface is much rougher than it appears to the naked eye alone, and tools need to be lapped on a diamond-impregnated wheel if their full value is to be realised for general machining operations.

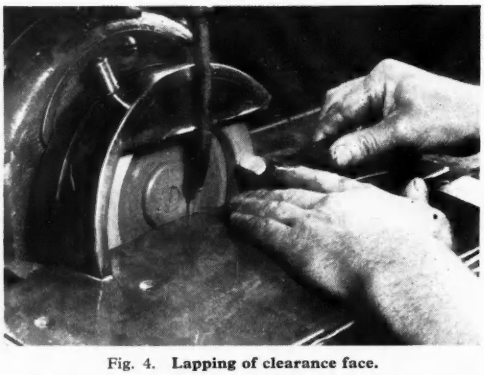


Fig. 4. **Lapping of clearance face.**

Diamond lapping is not as effective for tools used on very severe operations as it is for tools on general machining operations. Where chip-breaker grooves are not called for, it has been found, by certain firms engaged in the heaviest types of machining work, that diamond lapping does not always give a performance superior to that obtained by finish-grinding with silicon-carbide wheels. Grinding-machine operators need superlative skill to obtain consistently good results. Outside the specialised field of very heavy machining, diamond lapping is undoubtedly the most effective method in general commercial use of obtaining the type of finish needed on carbide cutting tools.

Steel can be diamond-lapped, but the lapping wheels will quickly load with steel particles and will cause heating. If a loaded lapping wheel is used on carbide, heat checks and possibly severe cracking will result. The wheel itself may be severely damaged. When servicing the harder grades of carbide, more care needs to be taken than with the softer grades of carbide. Particular care must be taken with the very hard steel-cutting grades, as these are more liable to heat checks than are other grades.

Table I shows grain size and structures of grinding wheels and lapping wheels recommended for use on machines in good condition. Hard wheels should be used only on machines which are in first-class condition throughout. Diamond lapping should be carried out on a machine which is adequately maintained. Where the tools are engaged on heavy-duty work, the hand-lapping operation is of the utmost importance. The breakage rate can be greatly reduced simply by inserting this operation where it has not been used before.

Very light shank grinding can be done dry. Heavy shank grinding should never be done dry unless gaseous coolants are used. If wet grinding is used, then there must be a copious supply of coolant. No benefit can be derived from letting coolant drip onto the tool; there must be a large volume of coolant directed at low pressure onto the area where grinding occurs.

When grinding the tip, either wet grinding or dry grinding can be used. If the tool is ground wet, then again there must be a copious supply of coolant. If ground dry, grinding pressures must be light and care must be taken to prevent overheating and cracking. The writer prefers wet grinding, but knows of many firms where dry grinding is used with great success, particularly on small-section tools, where the amount of heat generated is not large and where the labour force is highly skilled and well experienced in this class of work.

Diamond lapping is the best method of finishing the general run of carbide tips, and chip-breaker grooves cannot be successfully produced by any other method. Given care and skill, dry lapping can be quite successful. It is certainly cleaner than wet lapping, where the high speed causes coolant to be flung violently from the wheel. Wet lapping, in comparison with dry lapping, gives a longer wheel life and a greater rate of metal removal. The finish is often better, and it is also easier to wet-lap harder and more difficult grades of carbide.

The writer wishes to thank the Directors of William Jessop & Sons Ltd. and J. J. Saville & Co. Ltd. for permission to use the information contained in this article and gives grateful thanks to all those from whom he has received aid in its preparation.

RECORDING OF TRANSIENT PHENOMENA IN MACHINE TOOLS

(*Concluded from page* 365)

In a second stage of the research, a study was made of this behaviour of the photographic paper, and it was found that the black spots were obtained as if the paper had been exposed and subjected to an ordinary developing process. This suggested that electric current might have a "photographic" effect, similar to that of light on sensitised material. However, careful examination disclosed that the sensitised surface of any type of photographic material is highly sensitive to electrical differences of potential. The effect of voltage on the condition of the sensitised surface is practically instantaneous, since it occurs in a time interval of the order of one microsecond.

Further research indicated that point-recording could be effected by means of this new method, without producing perforations. The arrangement for this type of recording, referring again to the basic equipment in Fig. 1 is as follows :—The sheet of photographic paper (*b*) has under it a sheet of insulating material of suitable thickness. The point (*p*) rests lightly on the cylinder and is connected to the transformer secondary, which also is connected to the sliding contact (*e*). Each signal pulse generates an instantaneous oscillatory voltage which sensitises the photographic paper at (*p*). The size of the recording point depends on the dimensions of the point (*p*) and the value of the applied potential. In this method, the recordings are naturally taken with the photographic paper completely shielded against light, and the strip is then developed in the usual way. In view of the extremely small amount of energy required to affect the strip, this method appears suitable for detailed analyses. In fact, it was not difficult to obtain by this means recordings of up to 1870 points per second.

The recording of operating conditions of machine tools by the point-by-point method, with detailed indications of transient phenomena, is thus both accurate and simple. For qualitative recordings, the fairly large points are fully adequate in usual applications; quantitative investigations can be made with greater precision by the special method just described. A detailed study of the phenomena observed should prove profitable, both for designers and users of machine tools.

Quality Control in Wire Drawing

By O. HERRMANN. (From *Draht*, No. 23, June 1954, pp. 26-30, 10 illustrations.)

Measurements of drawing force have demonstrated that it may be used as a criterion for the uniformity of drawing conditions. This article describes a drawing-force indicator which informs the operator of any variations in drawing conditions, thus ensuring uniform quality. Furthermore, it facilitates inspection and shows whether a new drawing die works satisfactorily in the existing set up.

IN all modern wire-drawing works, continuous quality control of the product is essential, not only for the final draft but also for the intermediate drafts, as faults in the intermediate stages may have harmful effects on the quality of the finished product. Inspection of the drawn wire mainly covers, among other details, the measurement of the diameter at the start and at the end of the reel (if possible, any deviation of the diameter within the length of the reel should be noted), as well as tests for roundness, surface quality, and physical properties of the drawn wire. All these tests can be carried out only on the finish-drawn wire. The problem therefore arose how to give the operator complete control over the wire-drawing process. For special high-quality wire, the use of single-stage bull blocks is customary for the final draft, and possibly also for the intermediate drafts. The operator often has several machines in his charge, thus making close supervision even more difficult. For the finish-drawing process, a device which correctly registers operating conditions would be of great advantage.

THEORETICAL CONSIDERATIONS

The conditions present in wire drawing govern the quality of the finished product and are influenced by various factors. Of primary importance is the degree of deformation to which the material is subjected, which can be expressed as $\log_e (F_0/F_1)$, where F_0 = cross-sectional area of the wire before drawing, and F_1 = cross-sectional area of the wire after drawing, or the amount of reduction of the cross-sectional area $\Delta Q = 1 - F_1/F_0$, which has a considerable influence over the drawing force P and the degree of work-hardening of the wire. Also of importance are the drawing angle 2α of the die, the resistance to drawing K_f [kg/mm²], and the friction conditions present in the die when in use, characterised by the friction coefficient μ. Tests by the author have shown that the speed of drawing influences not only the drawing force, but also the magnitude of the final diameter, and thus the actual reduction applied to the wire. Furthermore, the drawing speed has a bearing on the work-hardening of the wire. In hot-drawing, to mention another example, the temperature of the undrawn wire and the temperature of the drawing die itself should not be overlooked when making drawing-force tests. The temperatures of the wire and of the die also determine whether cold or hot work-hardening is taking place and thus substantially govern the magnitude of the resistance to drawing K_f. Wires which are used at higher temperatures are subject to a loss of strength and to a change in their structure, i.e., they are recrystallised. This recrystallisation may be influenced by the conditions of the draft and is thus important for the quality of the drawn wire. The change in resistance during drawing depends on the conditions of the draft, and determines the behaviour of the wire during recrystallisation. In consequence, drawing conditions should be strictly observed when dealing with material having a fine-grained structure.

For the smallest drawing forces, the friction coefficient μ, the degree of deformation $\log_e (F_0/F_1)$, and the die-orifice angle 2α must be in a certain relation to each other. The author has supplied the following formula :—

$$\sin 2\alpha = \sqrt{6\mu \times \log_e (F_0/F_1)}$$

As an example, assume the following drawing conditions which satisfy the equation :—

Reduction of cross-sectional are	$\Delta Q = 10\%$
Coefficient of friction	$\mu = 0{\cdot}05$
Diameter of wire before drawing	$D_0 = 200$ microns
Drawing angle	$2\alpha = 10{\cdot}2$ deg.

The result, in figures, is a drawing force $P = 1{\cdot}255$ kg (2·76 lb), when $K_f = 200$ kg/mm² (127 tsi).

During drawing, the coefficient of friction may be subjected to considerable changes. This may be caused by variation in the supply of lubricant, a possible change in the polish of the drawing die, and by a variation in the surface condition of the wire. Thus, for example, if the coefficient of friction μ is increased by 100%, the drawing force rises by approximately 25%. Such a variation in the coefficient of friction frequently occurs in actual practice. However, the drawing force is also substantially affected by a change in the diameter of the wire before drawing and by the change in the reduction of the cross-sectional area thus caused. Thus, a change of 1% in the cross-sectional area of the wire before drawing entails a 7% increase in the drawing force. Naturally, changes in the reduction of cross-sectional area may occur when the cross-sectional area of the wire before drawing remains constant, due to increasing wear of the die, and result in a larger diameter of the drawn wire. In cone-shaped dies, increasing wear should not, generally, lead to a change in the drawing angle which might materially affect the magnitude of the drawing force. Conditions are different for dies with a bell-mouthed orifice, where increasing wear and a change in the diameter of the wire before drawing result in a change in the effective drawing angle. However, even when a different die is used, a change

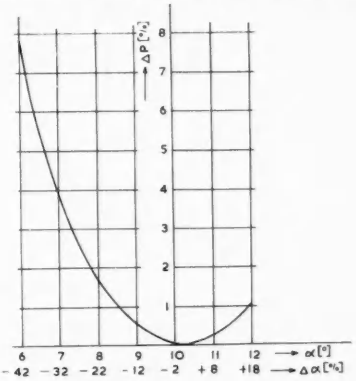


Fig. 1. **Influence of die-orifice angle on drawing force.**

in the drawing angle may be indicated. Fig. 1 shows the relationship, in per cent, between the drawing force and the drawing angle. Since the assumed conditions of the draft satisfy the equation, the drawing force increases with a larger, as well as with a smaller, drawing angle. If the orifice angle α is small, the ratio μ/α, which represents the frictional force, becomes very large, while the proportion of the axial force, as part of the total drawing force $\alpha/\log_e (F_0/F_1)$ becomes smaller. The conditions are reversed for a large angle α. The problem is very much more involved for drawing dies with a bell-mouthed orifice. Fig. 2 shows (still for the

above example) the calculated shape (not drawn to scale), having for every starting diameter a mean orifice angle which, with an assumed constant coefficient of friction of 0·05, satisfies the equation. The wear of the die at the narrowest point affects not only the cross-sectional area through a change in the diameter D_1 of the drawn wire, but also the mean drawing angle 2α of the die.

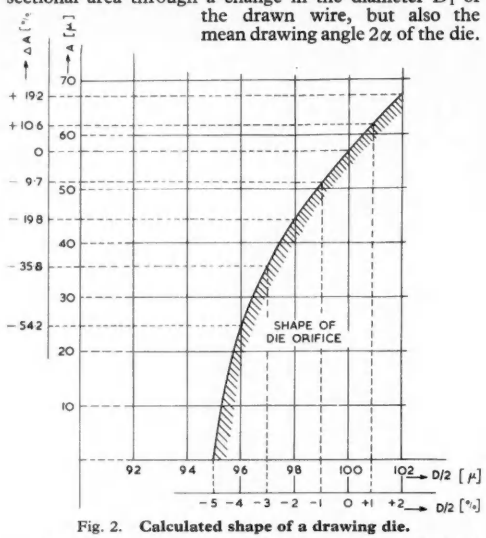


Fig. 2. **Calculated shape of a drawing die.**

Fig. 3 shows the calculation in the case of ideal wear, i.e., when the die is enlarged cylindrically at the narrowest diameter, of how drawing force is affected when the change in cross-sectional area and in die-orifice angle is taken into consideration. Remarkable in this diagram is the fact that, even with a very minute reduction in cross-sectional area, i.e., at a very small drawing angle, the drawing force has fallen to only 65% of its original value. When the orifice angle α is very small, the frictional force forms a large proportion of the total drawing force. As, furthermore, the rate of reduction in area diminishes together with the drawing angle, for this assumed increase in wear, no substantial

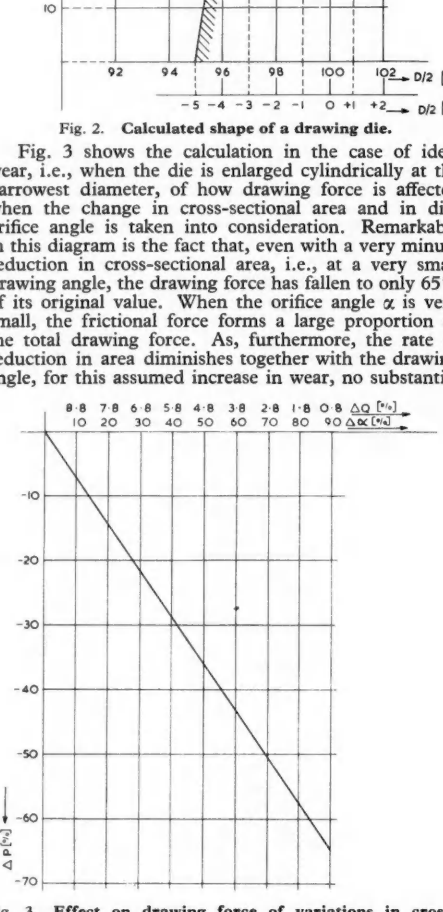


Fig. 3. **Effect on drawing force of variations in cross-sectional area and die-orifice angle.**

reduction in axial force takes place. Owing to the low effective power and to the high frictional and axial forces, the drawing efficiency is very low. The assumed theoretical wear, however, is not confirmed in actual practice ; the calculation was quoted merely to demonstrate that the relationships are very involved. The wear of the drawing die does not consist of a cylindrical widening of the die orifice, commencing at the bearing surface, but starts at that point on the entrance bell where the incoming wire touches the die and produces an annular widening which increases the mean drawing angle. This means that the changing shape of the orifice during the life of the die certainly exerts a different and greater influence over the drawing force than that shown in Fig. 3.

It is evident that the magnitude of the drawing force is a particularly accurate criterion of existing drawing-force conditions, and this has been confirmed by measurements of the drawing force. All these observations lead to the conclusion that the magnitude of the drawing force can show the operator whether the machine is functioning properly. Equal drawing conditions, which normally exist, result in a certain drawing force. Every alteration of drawing conditions is reflected in the magnitude of the drawing force. A drawing-force indicator would thus greatly facilitate the control of the drawing operation.

Diamond dies, after producing different lengths of wire, become useless through the appearance of cracks, flaws, and bad surface polish. These faults are not always recognised immediately during normal operation. This has a bad effect on the quality of the drawn wire and may also lead to the total loss of the diamond die, if it cannot be salvaged by enlarging it to a greater diameter. In order to overcome this difficulty, it has often been suggested that diamond dies be removed from the wire-drawing machine after they have reached a certain output, so that they can be inspected and re-polished, if necessary. This method has proved more economical than leaving the die unexamined in the machine for the remainder of its useful life. A drawing-force indicator would eliminate these difficulties.

Drawing-Force Indicator

The operation of a drawing-force indicator is shown diagrammatically in Fig. 4. The drawing force acts

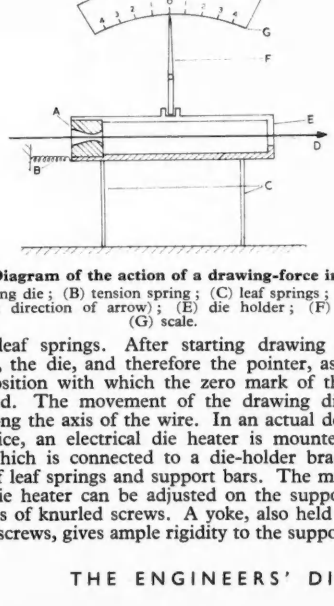


Fig. 4. **Diagram of the action of a drawing-force indicator.** (A) Drawing die ; (B) tension spring ; (C) leaf springs ; (D) wire (drawn in direction of arrow) ; (E) die holder ; (F) pointer ; (G) scale.

against leaf springs. After starting drawing on the machine, the die, and therefore the pointer, assume a mean position with which the zero mark of the scale is aligned. The movement of the drawing die takes place along the axis of the wire. In an actual design of this device, an electrical die heater is mounted on a sleeve which is connected to a die-holder bracket by means of leaf springs and support bars. The mounting of the die heater can be adjusted on the support bars by means of knurled screws. A yoke, also held by two knurled screws, gives ample rigidity to the support bars.

The horizontal movement of the die holder is transmitted to a pointer by means of a link mechanism. The pointer sweeps over a scale, the zero point of which is in the centre. At each end of the scale are mounted electrical contacts in such a way that they can be moved to any desired distance from the zero point of the scale. It is possible to tilt the scale mounting, including a lamp which is supplied from a 6-volt transformer by means of a flexible cable, to the left or right. The mean position of the die holder can be adjusted to any desired point. The drawing-force indicator is so designed that the warning lamp will be noticed by the operator, even though he may have several wire-drawing machines under his charge.

When the die has been inserted in the die heater in the usual way, the wire is threaded and the draw bench started up. The mean position of the die holder can then be adjusted, if necessary, in any desired way. The scale mounting is then tilted until the oscillating pointer of the device indicates zero on the scale. The electrical contacts are then adjusted so that the warning lamp indicates either large or small changes in the drawing force, as required by the particular circumstances. When the pointer touches the two spring contacts, it closes a circuit and causes the warning lamp to light up. Thin wire is used for the contacts and end stops, in order to prevent any bending of the pointer if the drawing force suddenly increases by a large amount.

Experience with drawing-force indicators of various designs has confirmed the view that a change in the drawing force indicates a change in drawing conditions. The absolute magnitude of the drawing force and its constancy are excellent criteria for the quality of the drawn wire. In hot-drawing, for example, the lubricant often burns and adheres to the entrance bell of the die, resulting in an uneven diameter of the drawn wire. The drawing-force indicator immediately warns the operator of this source of trouble.

U.S.A.

"Kanigen" Electroless Nickel Plating.

By G. Gutzeit. (From *Metal Progress*, Vol. 66, No.1, July 1, 1954, pp. 113-120, 146, 5 illustrations.)

Although electroless nickel plating is by no means new, it would appear that the "Kanigen" system has many advantages over earlier methods. The chemistry, characteristics, and applications of this new process are described in the accompanying article.

Nickel plating by chemical catalytic action differs from electroplating in that neither electrodes nor current are required for its application. Deposition takes place at a uniform rate wherever there is contact between the part and the solution; in other words, the "throwing power" of the bath is infinite, and there is no substantial variation in plating thickness, even for the most complicated shapes. The coating is a low nickel-phosphorus alloy of considerable hardness and higher corrosion resistance than electroplated nickel, and the as-plated deposit is non-porous even at less than 0·2 mil thickness.

The "Kanigen" nickel-plating process is based on the pioneering work performed by Brenner and Riddell of the electrochemical laboratory of the U.S. Bureau of Standards, although the basic reaction was discovered by Wurtz in 1844, and a U.S. patent issued in 1916 disclosed qualitatively the use of solutions containing hypophosphite ions for nickel coating most base materials.

The hypophosphite anion in an aqueous medium is oxidised to the phosphite ion, slowly at low temperature and rapidly at higher temperatures, while hydrogen is evolved. This oxidation takes place spontaneously (homogeneous reaction) at pH values above 7·0, but, in an acid medium, the presence of a catalyst belonging to group 8 of the periodic system is required (catalytic heterogeneous reaction). The equation, according to Wurtz, Bach, and Brenner, is :—

$$Na(H_2PO_2) + H_2O \rightarrow NaH(HPO_3) + H_2 \qquad (1)$$

If the aqueous hypophosphite solution is relatively concentrated and contains cations of heavy metals which can be reduced, such as nickel, cobalt, copper, silver, and gold, a spongy metallic precipitate forms when the solution is heated.

Moreover, if the cation in solution is that of a catalytic metal, and a catalytic solid surface is immersed in it, plating will take place on this surface (provided the proper concentrations are chosen), and continue until the solution is depleted of hypophosphite ion or of its metallic cation. According to Brenner and Riddell, the gross equation is :—

$$Ni\,Cl_2 + Na(H_2PO_2) + H_2O \xrightarrow{\text{catalyst}} Ni^{\circ} + 2H\,Cl + NaH(HPO_3) \qquad (2)$$

Actually, the chemical mechanism is considerably more complex. Without going into details, it is considered that the primary reaction is a catalytic dehydrogenation of hypophosphite (determined with the use of deuterium-tagged reagents), as follows :—

$$(H_2PO_2^-) \xrightarrow[\text{catalyst}]{-2H} PO_2^- + H_2O \rightarrow H(HPO_3)^- \qquad (3)$$

hypophosphite ion — metaphosphite ion — orthophosphite ion

Part of the atomic hydrogen thereby formed is possibly adsorbed on the catalytic surface as a condensed layer, reducing the nickel salt to metallic nickel :—

$$Ni^{++} + 2H \rightarrow Ni^{\circ} + 2H^+$$

$$\text{or} \quad Ni\,SO_4 + 2H \rightarrow Ni^{\circ} + H_2SO_4 \qquad (4)$$

It is assumed that the metallic nickel immediately reacts with hypophosphorous acid (at a much slower rate) to form phosphides, as :—

$$6\,Ni^{\circ} + 2H(H_2PO_2) \rightarrow Ni_5P_2 + 3\,H_2O + NiO \qquad (5)$$

Kanigen Method of Plating

As a result of the work carried out for over five years by the Research and Development Department of the General American Transportation Corp., of Chicago, in an effort to discover a process of chemical nickel plating which would not have the known drawbacks of the original Bureau of Standards method, and after considerable experimentation with the plating baths described in the Bureau of Standards publications, and many possible variations of such baths, it was found that concentrations of solution components and strict control of initial pH were critical in the acid baths, insofar as plating rate and quality were concerned. It has been disclosed* that there is an optimum range of ratios of nickel ions to hypophosphite ions at an optimum absolute hypophosphite concentration.

If the nickel-to-hypophosphite ratio is below 0·25, the plate has a dull grey, non-metallic appearance. If this ratio is above 0·6, the rate of deposition becomes very poor. A high concentration of hypophosphite ions results in instability, while a low anion concentration

*U.S. Patent No. 2,658,841.

again slows deposition. Other factors of lesser importance also influence the quality of these deposits.

It should be pointed out that the preferred conditions are always a function of the quality of the bath. Using sodium acetate as a buffer, an alkali hypophosphite, and nickel chloride, best results are obtained with baths to these limits :—

Ratio of nickel to hypophosphite ions ..	0·25 to 0·60 mol
Hypophosphite concentration	0·15 to 0·35 mol
Initial pH	
Na^{+}	4·6 to 5·5
Ca^{++}	5·0
Buffer concentration ..	0·120 mol
Ratio of solution volume to catalytic area	10

Even under these optimum conditions, the plating rate is too slow and will not meet the minimum requirements of industry. It was discovered that the addition of certain organic anions (for example, unsubstituted short-chain aliphatic dicarboxylic acids) will substantially raise the speed of deposition up to values of 1·5 mils per hour—an increase of 3 to 5 times over those obtained by Brenner and Riddell. In addition, bath stability in batch operation is enhanced. The effect of these reagents is to loosen the bond of the hydrogen atoms attached directly to the phosphorus atom in the hypophosphite molecule by complex formation.

As can be seen from eq. (3), the hypophosphite anion consumed by the reaction is oxidised to phosphite ion. While nickel hypophosphite is very soluble, nickel phosphite is not. Accordingly, as plating proceeds and the concentration in phosphite increases to the critical threshold, a precipitate will form in the bath (Brenner's " basic salts "). This not only results in rough deposits, but the solid particles (even those of submicroscopic size) act as decomposition nuclei and random precipitation of metallic nickel occurs, which, in turn, functions as a catalyst. Several additives were developed, to retard considerably the precipitation of nickel phosphite, without substantially impairing plating rate or quality.

When plating is performed as a batch operation, whether discontinuous or semi-continuous, the deposit cannot be homogeneous in the vertical direction, because composition of the bath is constantly changing through depletion of nickel and hypophosphite ions and through increased concentration of phosphite and hydrogen ions. As a matter of fact, the work of the National Bureau of Standards has shown that this coating has a stratified structure. It has been discovered that continuous circulation, filtration, and regeneration are required to keep the bath composition substantially constant in production.*

Regeneration, or the continuous feeding of the necessary chemicals to the bath in amounts equal to those consumed by the plating reaction, can be automatically controlled by instrumental analysis of the variation of one single constituent, others being fed in fixed proportions. On the other hand, while it is desirable to add these chemicals as solutions of virtually saturated strength, this cannot be done when the bath is at an elevated temperature. Local decomposition will then occur in zones of high concentration.

The plating system, incorporating the stated conditions, is as follows :—The plating bath is stored at a maximum temperature of 150° F in a reservoir of sufficient capacity (Fig. 1), whence it flows into the plating tank through a heat exchanger which raises its temperature to between 208 and 212° F. From the plating tank it goes through a cooler, bringing it back to below 150° F, then into a regeneration vessel where reagents are added in automatically controlled amounts, so as to bring the solution's components to their original concentration. The liquor then runs into a filter. Finally, the bath is returned to the storage reservoir.

*U.S. Patent No. 2,658,839.

Cooling and heating are effectively carried out by means of a special procedure. To decrease the temperature, the necessary amount of solvent (water) is flash-evaporated by vacuum. This results in concentration of the solution. Heating is accomplished by injecting steam in such a manner that the dilution due to the condensate produced will balance exactly the loss caused by flash-cooling (Fig. 2).

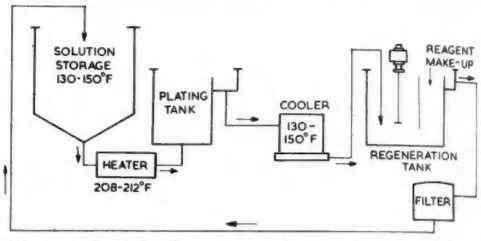


Fig. 1. **Schematic diagram of equipment for maintaining continuous circulation, filtration, and regeneration of the bath.**

When operating as described above, plating-bath composition stays constant and, therefore, the deposit has a maximum of homogeneity and is bright, dense, and free from pores.

It was found that the continuous heating-cooling cycle is likely to cause thermal decomposition. In other words, the plating solution, after a certain number of cycles, becomes relatively unstable. This led to the development of specific stabilisers, some of which, in addition to their principal function, favourably influence deposition rate and coating appearance.

Composition and Properties

The principal properties of Kanigen plating may be summarised as follows :—

Chemical composition (average) :—Phosphorus 7%, nickel 92%.

Structure :—Probably amorphous.

Hardness (as deposited) :—Vickers 500 (about Rockwell C-49).

Corrosion resistance :—At least equal to, and generally better than, wrought nickel.

Coefficient of expansion :—7·22 × 10^{-6} in. per in. per ° F.

Electrically resistivity :—Approximately 60 microohms per cm.

Adherence :—Excellent on steel and copper alloys; good on ferrous alloys, aluminium, and on thermosetting plastics.

Porosity (as deposited) :—No porosity for a minimum thickness of 0·2 mil.

Melting point :—Between 2000 and 2190° F.

With the standard acid solutions, the coating averages 7% phosphorus. It is highly probable that the phosphorus is present as a solid solution in nickel, and that the deposit is amorphous (as shown by chemical tests and X-ray diffraction).

By heat-treating at 750 to 930° F for one hour in a reducing or inert atmosphere, the hardness can be raised to from Vickers 500 or 600, to 900 (Rockwell C-64). A heat treatment at about 1110° F for 1½ hr results in a hardness at room temperature of Vickers 700, but the ductility is increased, so that wear resistance is improved.

Heat treatment at about 1470° F for 1 hr will produce a room-temperature hardness equal to or below the original value, depending on the kind of plating bath used. Thus, one kind of coating will have a hardness of Vickers 250 after 1 hr, with good ductility, permitting considerable bending without stress failure. The hot hardness of Kanigen above 750° F (i.e., the hardness at elevated temperature) is low, and coated

parts are unsuitable for applications above this temperature, especially where abrasion is involved. The hardness of the coating usually gives good abrasion resistance, particularly if properly lubricated.

Corrosion resistance of Kanigen plate is at least equal to and generally better than that of pure nickel. This is due to the phosphorus content of the deposit. The amorphous character of these coatings (which do not show a crystalline structure in X-ray diffraction studies) also may account for their higher corrosion resistance.

Research work has established by circumstantial evidence that, in the case of thoroughly cleaned and Kanigen-plated mild steel, a close relationship exists between surface inhomogeneity of the base metal and the salt-spray resistance of the overlaid plating. These inhomogeneities on the base-metal surface are probably caused by local variations in Kanigen composition (possibly phosphorus content), which, in the presence of a corrosive electrolyte such as brine, create galvanic action and induce porosity. For that very reason, a thin undercoating of copper on mild steel gives amazingly high resistance to salt spray. Of course, any accidental local impurity on the base-metal surface, such as smudges, grease film, and oxide layers, will impair adherence, as well as salt-spray resistance.

There is also evidence that the quality of plant water or, more specifically, seasonal variations in water pollutants, can affect salt-spray resistance. It can, however, be stated that the average salt-spray resistance of Kanigen is at least twice that of electrolytic nickel plate.

Another important characteristic of these coatings is that, whenever rust spots appear as a result of salt-spray testing, they do not spread upon continued exposure to the brine fog; this is contrary to what is always observed with electrolytic nickel coatings. This fact represents one of the biggest advantages of Kanigen.

The adhesion of Kanigen deposits to low-carbon steel, to copper alloys, and to nickel can be termed excellent. No flaking occurs from a 180-deg. bend over a 2-in. diameter mandrel. Upon reverse bending to 180 deg., some crushing and slight powdering occur in the compression zone, particularly when the deposits are thicker than 2 mils, this being on account of the hardness of the coating. A direct bend to 180 deg. over a 3-in. mandrel followed by a 180 deg. reverse bend, shows no flaking or cracking visible to the naked eye. It has been proved that, as long as the base metal is not permanently deformed, excellent protection is afforded by these coatings. The plating shows no failure in tensile tests prior to the point at which the base metal exceeds its elastic limit and breaks. No peeling occurs at a distance greater than $\frac{1}{16}$ in. from the break.

The adhesion of Kanigen deposits to aluminium, steel, and stainless-steel alloys is good when specially developed pretreatment methods are applied. This is being constantly improved. Adhesion to thermosetting plastics, ceramics, and glass varies from good to fair, depending on the type of base material. Adherence to these is mechanical rather than physico-chemical.

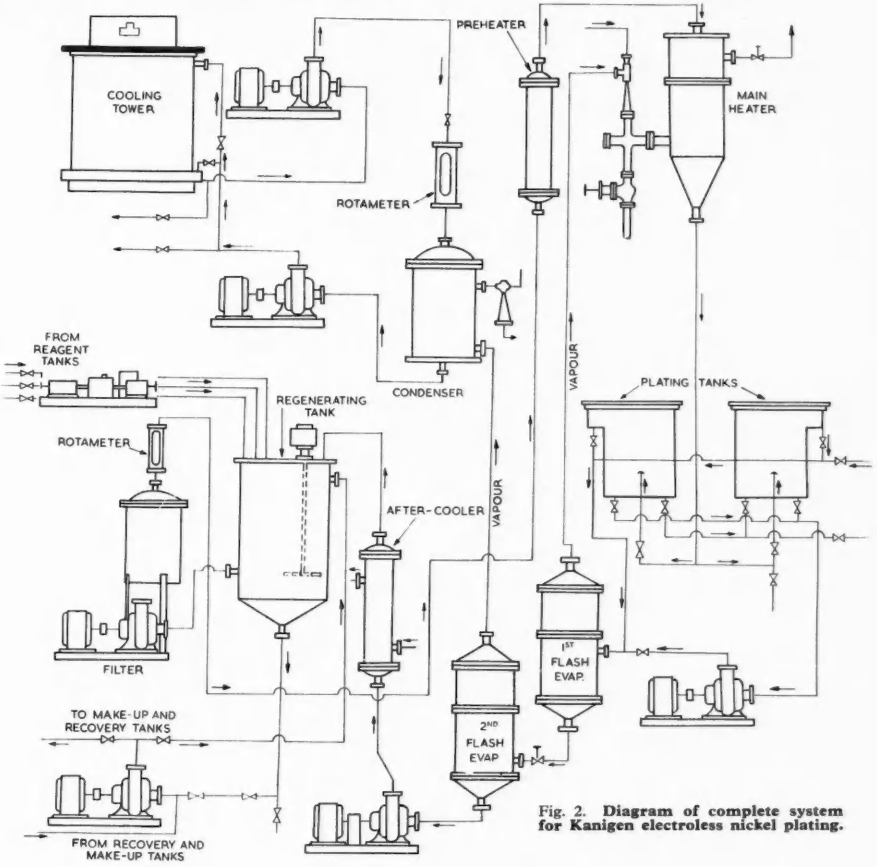


Fig. 2. Diagram of complete system for Kanigen electroless nickel plating.

Furthermore, it has been demonstrated that Kanigen deposits, when plated on a metal of reasonably good quality, are non-porous at thicknesses of 0·2 mil and more.

Physical Character of Coatings

The uniformity of the thickness can be kept within less than 10%; for example, for a specified thickness of 0·001 in., the extreme variations would be 0·0009 to 0·0011 in. With care, even closer tolerances can be obtained.

Although, in continuous operation, the coating can be deposited to any desired thickness, it is impractical to exceed 6 to 7 mils, particularly for a plant on a one-shift schedule. Actually, full protection is afforded by 0·5 to 1 mil in a non-corrosive medium (corrosiveness being here taken as related to Kanigen). In mildly corrosive service, a thickness of 5 mils is generally sufficient to resist liquids or gases for which electroless nickel plating is considered suitable.

These coatings reproduce the character of the underlying surface with a slight smoothing effect. A highly polished part, after plating, will have a mirror-like appearance without additional buffing, while a rough casting will be just as rough when removed from the bath. The " colour " of the coating is a metallic light-grey with a slight yellow tinge. A special additive produces a white colour, without increasing the optical coefficient of reflection.

An after-treatment has been developed to blacken the Kanigen surface. It is interesting to note that pure nickel does not respond to the same process. In a corrosive atmosphere, ordinary Kanigen will slowly tarnish (as does pure nickel) without losing any of its physical qualities. As a matter of fact, its chemical resistance appears to increase through ageing.

Principal Applications

The infinite " throwing power " of this process and the attendant uniformity of deposit and its protective qualities make it ideally suitable for use on irregular or complicated shapes of ferrous alloys, copper, brass, bronze, and aluminium which are difficult or impossible to plate by conventional methods. This use is particularly advantageous with items such as unusually large pieces or tanks; complex fabricated assemblies; forgings and castings; parts having screw threads, indentations, or holes which must be uniformly coated with a protective deposit; and the interiors of vessels, tubes, and pipes. The coating offers possibilities as an economical alternative for nickel and some of the special alloys used in assemblies which must be corrosion-resistant, since the Kanigen lining can be deposited on an inexpensive base, e.g., mild steel or brass.

Plating of Kanigen on nickel (whether electrolytically deposited or otherwise), on nickel alloys, and on itself is easy. Plating on sintered-metal shapes gives excellent results, with no peeling or bleeding occurring in storage or use.

The coating cannot be applied on lead, cadmium, zinc, tin, and antimony, nor on surfaces that have been contaminated with them (as on cadmium plate and galvanised iron). This precludes chemical plating on parts soldered or brazed with tin or lead alloys. On the other hand, some alloys in which these metals are used in small proportions, such as certain bronzes, plate satisfactorily.

Adhesion on stainless steels, molybdenum, and other alloy steels is variable. Generally, a special treatment is required to obtain best results. Good adherence is difficult or impossible to obtain on casting alloys of aluminium and steel which contain a high percentage of silicon. Chemical plating on zinc die castings is best performed over a thin electroplate of copper. This will impart better adhesion and durability of the final plate. Direct chemical plating on magnesium is still in the development stage.

In view of the uniformity and the lack of porosity of deposits, no allowance has to be made for depressions, and no large safety factor is required. If the specification calls for a deposit of 3 mils, a factor of plus 10% is sufficient. This permits large savings in nickel and consequently in plating costs. The high uniformity of the plate gives greater freedom in designing parts for best application and most economical fabrication. The only precaution to be observed in design is to avoid pockets where the hydrogen evolved in the process could be trapped to prevent plating.

The coatings can be soldered with ease, provided the temperature is sufficient for obtaining flow. Rosin-core solder provides excellent adhesion. For ordinary solder, the recommended flux is 40 parts of saturated solution of rosin in methyl alcohol and 1 part 85% phosphoric acid. Although Kanigen-plated pieces can be arc-welded with an inert-gas-shielded pure nickel rod, there is generally enough phosphorus pick-up to result in a brittle bond. It is therefore advisable to perform all welding before plating.

An interesting special application of the Kanigen process is to make aluminium solderable. A very thin coating, of about 0·00005 in., obtained by a quick dip, is sufficient for this purpose. Aluminium can also be tinned after it receives this pretreatment. Copper, gold, chromium, and other metals can be plated over Kanigen coatings by using standard methods.

In order to deposit Kanigen on non-metallic materials such as thermosetting plastics, ceramics, and glass, a particular pretreatment is required. The resulting bond is mostly mechanical (except in specially formulated plastics), and is therefore relatively weaker than with metals.

In view of the temperatures at which the bath is operated, plastic materials with a low softening point are not suitable for plating. Even the heat-resisting thermosetting materials, such as the bakelites, sometimes contain fillers which have high water absorptivity and, therefore, will show an " orange-peel " effect on the surface of the coating. Mineral-filled phenolics generally take excellent plating, with good adhesion and no flaking, even upon breaking the part.

Porcelain, stoneware, and similar ceramics can be coated with an adherent deposit, provided they are not glazed. Glass must be frosted mechanically or chemically before plating. The resulting deposit is dull and not suitable for optical purposes, unless it is polished. The adherence to glass is only fair. Most uses of the plate on non-metals should be directed towards obtaining a seal or a solderable surface, a base for electroplating a more conductive coat, a moisture barrier, or a hard, abrasion-resistant surface.

Economic Considerations

The cost of Kanigen processing for industrial purposes can be compared only rarely with that of electroplating. When substitution is possible, electroplating is, at present, somewhat cheaper; however, on the basis of the uniformity and non-porosity of Kanigen, substantial savings are possible by lowering the safety factor to 10% and by using the thinnest coating that will still give full protection.

In the decorative field, electroplating is generally less expensive, unless the design of the part precludes the use of electrodes. Generally speaking, this electroless plating method is competitive with electroplating, whenever the latter is applicable, although technical considerations (such as higher corrosion resistance, and greater hardness) might be in favour of the electroless coatings. In a number of instances, electroplating cannot be used at all, as for fabricated equipment such as screw-conveyer sections, or for intricate shapes such as valves, complex housings, gears, and screw assemblies.

Economics of the Steam Cycle in Nuclear Power Stations

By J. L. D'EPINAY and W. LÜTHI. (From *Brown Boveri Mitteilungen*, Vol. 41, No. 3/4, March/April, 1954, pp. 101-107, 9 illustrations.)

A STEADILY increasing world demand for energy is causing increasing anxiety about the adequacy of known sources. Coal reserves are showing disturbing signs of depletion, and the man-power problem is becoming more and more acute ; available hydro-electric energy may reach the limit of economical exploitation in the next 20 or 30 years ; and wind, tidal, and solar energy cannot be continuously exploited by present-day engineering methods.

Intensified search has therefore been focussed upon the new source of energy offered by nuclear fission. Theoretical and technological developments in this field lead experts to believe that long before the end of this century nuclear energy will be utilised in even the largest power stations, thus contributing considerably towards the reduction of the deficit between world energy demand and supply, even though the economics of the proposition have yet to be proved.

BASIC DESIGN OF THE POWER STATION

A cycle converting nuclear energy directly into power does not yet exist. However, the heat released as a by-product during the fission process in a nuclear reactor can be exploited suitably in a power station by way of a heat cycle. To shield the generating equipment from radioactive contamination due to the primary coolant, a heat-exchanger has to be interposed between reactor and turbine, using preferably ordinary water in the secondary circuit. Fig. 1 shows such a plant diagrammatically. The radioactive components, i.e., reactor (1), primary coolant circulating pump (2), and heat exchanger (3), are screened from the power-plant proper, i.e., the turbo-generator (5) condenser (6), feed-water heater (7) and feed pump (8). The advisability of installing a superheater (4), fired separately with conventional fuels, will be commented upon later.

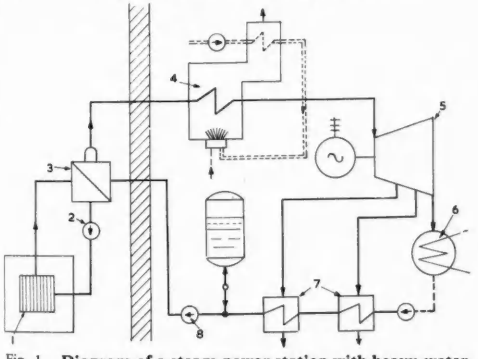


Fig. 1. **Diagram of a steam power station with heavy-water moderated uranium reactor.**

High live-steam temperatures, though desirable, cannot, at present, be used owing to difficulties of a nuclear-physical and metallurgical nature. The temperature in the reactor must therefore be kept under 300° C, in which case a saturated-steam cycle will give the turbine undeniable advantages over all other prime-movers, the ideal Carnot cycle being very closely approachable by the use of bled-steam feed-heating, combined with repeated condensate extraction.

FEEDWATER HEATING

(1) *Available Enthalpy Lost in a Feed-Heater.*

The general definition of available enthalpy is :—

$$i' = i - T_o\, s \qquad .. \qquad .. \qquad (1)$$

where i = enthalpy supplied, T_o = ambient temperature, s = entropy, $T_o\, s$ = heat dissipated to ambient, i' = enthalpy theoretically available for useful work taking, for example, heater No. IV of the feed-heating plant shown in Fig. 2, the heat exchange between the

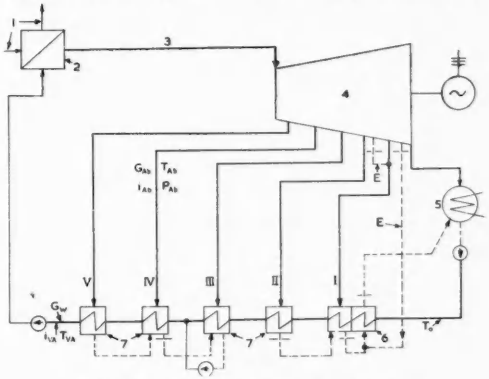


Fig. 2. **Example of a feedwater heating plant.**

(1) Reactor coolant.
(2) Heat exchanger.
(3) Saturated steam.
(4) Turbine.
(5) Condenser.
(6) Feed-heater with drain cooler.
(7) Feed-heaters.

G_W = Quantity of feedwater.
i_{VA}, T_{VA} = Enthalpy and temperature of feedwater at the outlet from the feed-heating plant.
i_{Ab}, T_{Ab}, p_{Ab} = Bled-steam conditions.
G_{Ab} = Quantity of bled steam.
E = Draining points.
T_o = Temperature of feedwater at inlet into the feed-heating plant.

bled-steam plus condensate on the one side and the feedwater on the other can be represented by the Q-η_c diagram, Fig. 3, where Q = heat exchanged, and η_c = the available fraction $(1 - T_o/T)$ of the heat either entering or leaving the cycle according to Carnot. On exchanging the amount δQ, the small, close-hatched area in the diagram will represent the loss between the available enthalpy supplied to, and that actually absorbed by, the feedwater. The entire hatched area of the diagram represents the total loss of available enthalpy incurred in heater No. IV. Introducing a mean co-efficient η_m for the bled steam and the condensate supplying the heat-input, the loss of available enthalpy can be formulated thus :—

$$\Delta i' = \eta_m\, \Delta Q_W - [\Delta Q_W - c\, T_o \log_e (T_a/T_e)].$$

Substituting for $\eta_m = 1 - T_o/T_m$

$$\Delta i' = c\, T_o \left[\log_e \frac{T_a}{T_e} - \frac{T_a - T_e}{T_m} \right] \qquad (2)$$

where c = specific heat of water, assumed to be constant ; T_o = inlet temperature of the feedwater into the heater-plant, at which the now available fraction of the enthalpy is dissipated. For other symbols, see Figs. 2 and 3.

(2) *Optimum Distribution of Feedwater Heaters.*

For a given final feedwater temperature T_{VA} and for a given number n of feed-heaters, the best distribution over the temperature range $(T_{VA} - T_o)$, consistent with the minimum of losses, is given by :—

$$\nu \sum_1^n \Delta i_\nu' = \text{minimum} \qquad .. \qquad .. \qquad .. \qquad (3)$$

where ν = index-number of heaters.

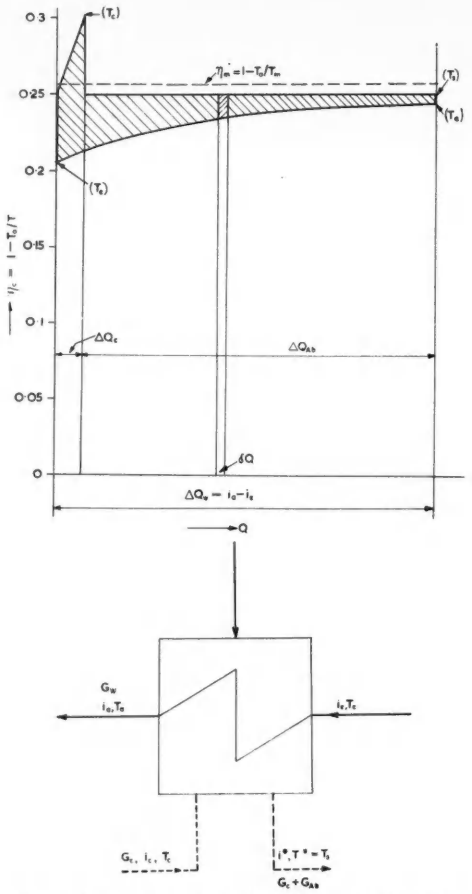


Fig. 3. **Heat exchange in feedwater heater No. IV of** Fig. 2.

i_e, T_e = Feedwater conditions at inlet.
i_a, T_a = Feedwater conditions at outlet.
G_c, i_c, T_c = Quantity and conditions of incoming condensate.
i^*, $T^* = T_s$ = State of condensed steam on the liquid line, T_s being the saturation temperature at p_{Ab}.
ΔQ_W = Heat absorbed by feedwater.
ΔQ_c = Heat extracted from condensate.
ΔQ_{Ab} = Heat extracted from bled steam.

Assuming, on the hot side, condensing steam only ($T_{\text{mean}} = T_{\text{saturated}}$), and

$$\epsilon = \frac{T_a - T_e}{T_s - T_c} \qquad \ldots \qquad (4)$$

to be identical for all heaters, the following law of distribution can be deduced :—

$$\left(\frac{T_a}{T_e}\right)_\nu = \left(\frac{T_{VA}}{T_o}\right)^{1/n} = \text{const.}, \quad \nu = 1 \ldots n \qquad (5)$$

i.e., the ratio of outlet temperature to inlet temperature of all heaters is constant.

(3) *Optimum Final Temperature of Feedwater Heating.*

The problem is to find, for a given number of feed-heaters, the final feedwater temperature which will give optimum efficiency.

It may be safely assumed that, at least for large outputs, the degree of exploitation η_M of the available enthalpy in the turbines is not influenced by small variations in T_{VA}, the final feed-heating temperature. Introducing, therefore, an efficiency expressed by the ratio of total available enthalpy i_{tot}' to heat-input from the outside Q_{os},

$$\eta = \frac{i_{tot}'}{Q_{os}} = \frac{i_F - i_{VA} - T_o(s_F - s_{VA}) - \nu \sum_1^n \Delta i_\nu'}{i_F - i_{VA}} \qquad (6)$$

and differentiating for η = max., $d\eta = 0$, and introducing for T_a/T_e the optimum value from eq. (5),

$$\nu \sum_1^n \Delta i_\nu' = c\, T_o \left\{ \log_e \frac{T_{VA}}{T_o} - \frac{n}{k}\left[1 - \left(\frac{T_{VA}}{T_o}\right)^{-1/n}\right]\right\} \qquad (7)$$

$$\text{where } k = T_m/T_a = T_s/T_a \qquad \ldots \qquad (8)$$

has the same value for all heaters I to n according to premises (4) and eq. (5).

Finally, there follows, for given values of n and k, optimum T_{VA} from

$$c\ (n+1) = (T_{VA}/T_o)^{1/n}\,(cn - k\Delta s_{oV}) + (T_{VA}/T_o)^{-1}\,[c + (\Delta i_{oV}/T_o)] \qquad \ldots \qquad (9)$$

In eqs. (6) to (9),

$i_F - i_{VA}$ = heat supplied to cycle with feed-heating, the subscript F denoting live steam.

$T_o(s_F - s_{VA})$ = heat dissipated from cycle with feed-heating.

$\nu \sum_1^n \Delta i_\nu'$ = total loss of available enthalpy in feed-heating plant.

Δi_{oV} = heat supplied to cycle without feed-heating.

$T_o \Delta s_{oV}$ = heat dissipated from cycle without feed-heating.

For a predetermined ϵ solve the equation with an estimated k-value for T_{VA}/T_o and thus T_a/T_e. Equation (4) will then yield a k-value corresponding to ϵ which will be sufficiently exact for a determination of the optimum final feed-heating temperature.

Assuming $\quad k = 1, \quad \epsilon = 1, \quad n \to \infty$

$$i_F - i_{VA} - T_o(s_F - s_{VA}) = 0 \qquad \ldots \qquad (10)$$

This equation can be satisfied only if the feed is heated to the saturated steam temperature.

Fig. 4 shows an evaluation of eqs. (9), (7), and (6), representing the optimum attainable efficiencies as a function of the number of feedwater heaters.

DRAINING

Expansion in a saturated-steam cycle takes place in the wet-steam region. All possible measures must therefore be taken to extract the condensate.

Fig. 5 shows the stepped expansion line of a draining arrangement, in which the wetness-fraction is reduced to 5% at every drain point. To increase the dryness-fraction x_B to x_C, say, at the drain point E_2, an amount of water has to be extracted given by

$$\Delta G_{tot} = G_{tot\,B}\left[1 - \frac{x_B}{x_C}\right] \qquad \ldots \qquad \ldots \qquad (11)$$

which is then used for feed-heating. Experience shows the pressure drop to be proportional to the mean wetness-fraction $(1 - x_m)$. For design purposes, this loss is expressed as $(1 - x_m)\beta$, where β is a "braking" coefficient, having a value near unity, depending on the mean wetness-fraction and turbine design details.

REHEAT

It is evident that an additional reheat cycle would improve the overall-efficiency of a saturated-steam cycle only if its partial efficiency were higher than that of the basic cycle without reheat. It can be shown, however,

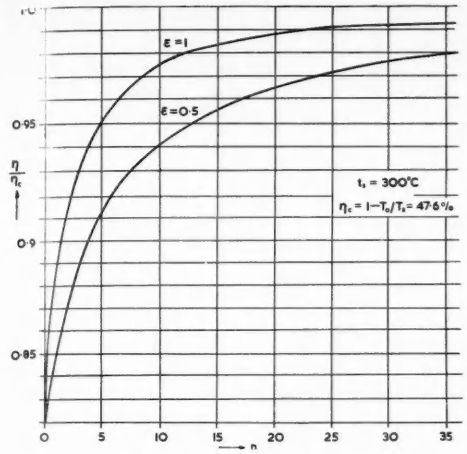


Fig. 4. **Efficiency graphs.**

η = Efficiency, as defined by eq. (6).
η_C = Carnot efficiency with t_s = 300° C.
n = Number of feedwater heaters.
ϵ = Coefficient defined by eq. (4).

that this is not the case if the mean reheat temperature T_{mR} is below the basic supply-temperature T_{mo}; if T_{mR} is above T_{mo}, the heat added is very small indeed.

components should be laid out to suit this principle. Design particulars, such as the surfaces of heat exchangers, cross-sections of piping, quantity of cooling-water, etc., influence cost and efficiency of the plant.

When all components of the plant have been economically balanced, any alteration in these items will result in a loss in economy. Hence, the following conditions will represent the optimum value for each of these parameters.

$$\Delta C(y) = a P \frac{\Delta \eta}{\eta}(y) \quad .. \quad .. \quad (12a)$$

$$\text{or } \Delta C(y) = (a + b) P \frac{\Delta \eta}{\eta}(y) \quad .. \quad (12b)$$

depending on whether the increase in efficiency is used for a reduction in fuel costs (eq. (12a)) or for an increase in output at constant energy input (eq. (12b)). In eqs. (12), ΔC = capital expenditure; P = output in kW; η = efficiency; a, b = capital costs specifically allowed per kW gained; and y = symbol for the component to be up-graded, the others remaining fixed According to the premises already mentioned, all the fixed components ought to represent their respective optimum values when applying eqs. (12) to the component (y); in practice, empirical values must provisionally be accepted, and they must all be re-assessed separately by application of eqs. (12).

The final feed-heating temperature represents a special case, as its change influences the efficiency, but not necessarily the cost, i.e., the economic optimum

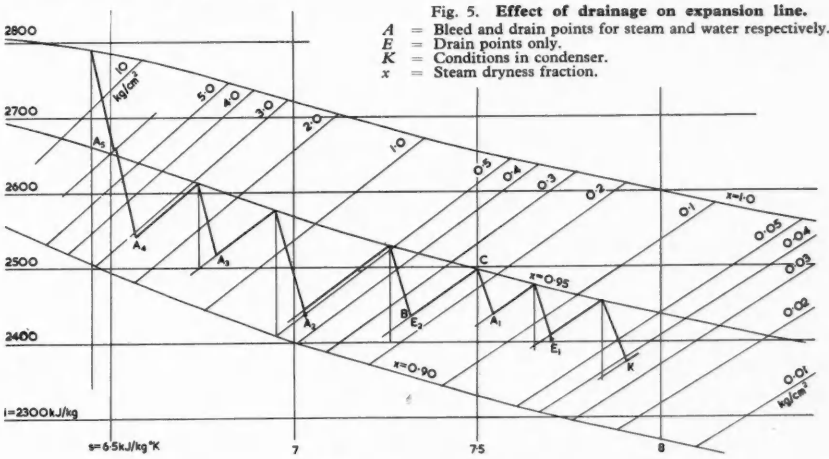


Fig. 5. **Effect of drainage on expansion line.**

A = Bleed and drain points for steam and water respectively.
E = Drain points only.
K = Conditions in condenser.
x = Steam dryness fraction.

Really good drainage will also dispose of the idea that, by diminishing the "braking losses" β through reheat drying of the partly expanded steam, a gain would result over and above the theoretical cycle-loss.

Superheating

The use of a superheater, fired separately with conventional fuels, is contrary to the concept of a nuclear power station; however, the addition of such a superheater, with its intrinsically high thermal efficiency, is one possible method of improving the economics of operating a basically nuclear plant.

Economical Proportioning Plant of Components

Every single component should be laid out according to the economical principle of "equal marginal effectiveness."* For the time being, research considerations only will govern the design of the reactor, but all other

coincides with the optimum efficiency. Finally, there arises the question of the economically justifiable number of feed-heaters, taking account of the conditions set out in eq. (5). Considering that there exists a relation between ϵ and the heat-exchanger surface F, an economically selected ϵ will fix the cost of the feed-heaters at the same time.

Having evaluated the efficiency by eq. (6) as a function of the number of feed-heaters n, with the help of eqs. (9) and (7), it will be easy to find the terms $a P \Delta \eta/\eta$ or $(a + b) P \Delta \eta/\eta$, as the case may be. Then, the number of feed-heaters may be increased until, when increasing from n to $(n + 1)$ heaters, the cost of one heater is $C_v > a P \Delta \eta/\eta$ or $C_v > (a + b) P \Delta \eta/\eta$, n representing the economically justifiable number of feed-heaters. All measures taken to improve efficiency will at the same time raise the net output of a nuclear energy plant without increasing the consumption of fissionable material.

*See *Brown Boveri Mitteilungen*, Vol. 37, No. 10, 1950, pp. 353-357.

Some Aspects of Spark Machining

By M. G. SEED, B.Sc.* and H. DRUBBA, Dipl.-Phys.*

THE use of very hard materials, such as carbides, for many engineering applications brings in its train the serious problem of machining parts made from these substances. Although grinding is possible with diamond-impregnated wheels, this process is limited to easily accessible surfaces; grinding of irregular internal surfaces is generally impracticable. Other machining operations, such as drilling, cutting, and milling, are practically impossible to perform satisfactorily; thus, for instance, extrusion dies made from these materials must be built up in sections, the internal surfaces of each of these sections being ground to final size. These sections are subsequently fitted together—a tedious process, requiring highly skilled labour.

These problems have been solved by the method of spark machining, introduced a few years ago, in which machining depends on the erosive action of a rapid succession of spark discharges between electrodes, one being the tool and the other the workpiece itself. Erosive action is greatly intensified by submerging both tool and workpiece in a suitable non-conductive liquid, such as paraffin. Apart from cooling, the effect of such a liquid can be compared with the results of an explosion in air as against those under water. The incompressibility of the liquid restricts energy release to a much smaller space, resulting in a considerable increase in energy density.

From the practical point of view, the main difference between spark cutting and conventional machining methods lies in the fact that, with spark cutting, tool wear is of the same order of magnitude as the amount of workpiece material removed, this ratio normally being about 1 to 6 by weight, depending on several factors, such as workpiece and electrode materials, electrical circuit, and the shape and cross-section of the electrode.

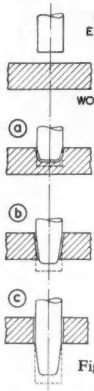


Fig. 1.

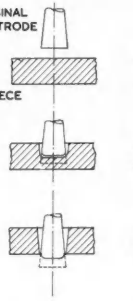


Fig. 2.

Fig. 3.

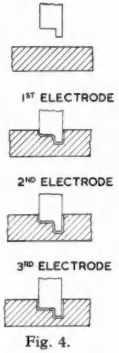


Fig. 4.

Fig. 1. **Cutting parallel holes with parallel electrodes.**

Fig. 2. **Cutting controlled tapers with reverse-taper electrodes.**

Fig. 3. **Sinking contoured blind holes with reverse-contour electrodes.**

Fig. 4. **Sinking contoured blind holes with one or more electrodes.**

Fig. 1 shows the progress of the cutting action, which commences when the gap between the tool electrode and workpiece has been narrowed down to the breakdown voltage. At the point of highest field strength, a spark will pass, pitting the workpiece and, to a smaller extent, the tool. The next spark will similarly discharge at another point where field strength happens to be highest, and this process will be repeated, the spark always following the locus of the highest field strength. Using an electrode with a sharp-edged contour and hence high field line density at the edges, a rounding-off effect will be observed. It will also be noticed that, after prolonged cutting, the electrode is not evenly eroded across its surface; this is due to the fact that the initial discharges occur at sharp edges, which are consequently rounded off to some extent; as a result, there will subsequently be a more even distribution of field line density.

Of course, the shape of the hole cut into the workpiece will at first be a replica of that of the tool. After deeper penetration (Fig. 1(a)), tapering of the sides and a rounding off of the bottom of the hole take place. This tapering will naturally be eliminated when the electrode has entirely passed through the hole, and that portion of the electrode which was not used for initial penetration now opens up the hole to size, as shown in Figs. 1(b) and (c). The sinking of deep, parallel-sided, blind holes, on the other hand, usually requires more than one electrode for final shaping, each new electrode producing a more faithful outline by removing the taper introduced by the previous cut (Fig. 4).

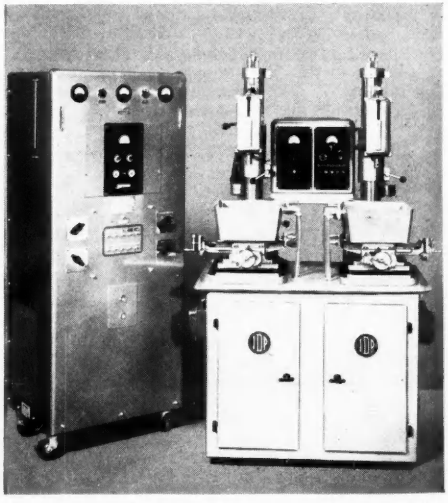


Fig. 5. **Latest type of "Sparcatron" spark-machining equipment.**

For certain die applications, however, tapering is often essential; in such cases, the tapering effect peculiar to spark machining can be put to useful purpose. Since tapers produced with parallel-sided electrodes are very slight, another method of producing more pronounced and controlled tapers has been successfully practised. This consists in tapering the electrode itself, as in Fig. 2, where it will be noticed that the wider cross-section of the tool contacts the workpiece first. The degree of electrode taper required to produce a given workpiece taper will depend on the ratio of electrode-to-workpiece wear. This feature of electrode wear is also demonstrated in Fig. 3, which shows how a contoured blind hole can be sunk with a reverse-contour electrode.

The latest type of "Sparcatron" equipment for operations of this kind is shown in Fig. 5. This equipment is provided with two servo-control electrode holders for simultaneous operation on two workpieces. The d.c. power supply is located in the control cabinet shown at the left of the illustration.

* Research Department, Sparcatron Ltd., Gloucester.

For the most satisfactory operation of spark machining, a thorough understanding of its principles of operation is necessary, requiring a study of its theoretical concepts and any deviations experienced in practice.

A machine using a relaxation type of circuit with a condenser charged from a d.c. source through a resistance will be considered. Some of the principles will also apply to similar machines using a condenser discharge as a spark initiator.

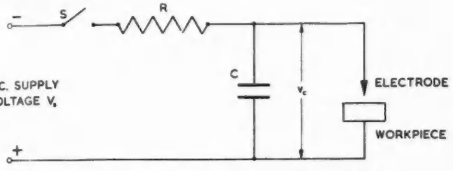


Fig. 6. **Basic circuit used in spark machining.**

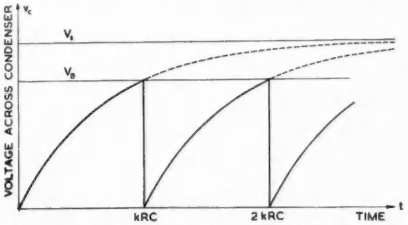


Fig. 7. **Variations in condenser voltage with time.**

In Fig. 6, C is a condenser, which may be connected to a d.c. source of voltage V_s by closing switch S. Assuming that the condenser is initially discharged, it will at first draw a heavy current from the supply, the value of which is limited by resistance R. When the condenser becomes charged, the voltage across it, v_c, increases, whilst the charging current decays as the condenser voltage exponentially approaches the supply voltage. The expression for the voltage across the condenser is given by :—

$$v_c = V_s(1 - e^{-t/RC}) \quad .. \quad .. \quad (1)$$

In other words, the condenser voltage approaches the supply voltage with a time constant equal to RC (Fig. 7). After a time $t = RC$, v_c is equal to 63% of its final value, and after a time equal to four times the time constant, i.e., $t = 4RC$, v_c equals 92% of its final value. However, in practice, the distance between the electrode and workpiece is adjusted so that the condenser discharges across this gap some considerable time before it reaches its final value at some value V_B after a time $t = kRC$. The energy stored in the condenser discharges in the form of a spark across the gap in a time which is small enough to be neglected in preliminary considerations. The voltage across the condenser drops to zero after this discharge, the initial conditions are re-established, and the cycle repeats itself.

The expression for the energy stored in the condenser at any instant is given by :—

$$W_c = \tfrac{1}{2} C v_c^2 \text{ [W-sec]} \quad .. \quad .. \quad (2)$$

where v_c is given in eq. (1).

Substituting for v_c :—

$$W_c = \tfrac{1}{2} CV_s^2(1 - e^{-t/RC})^2$$

Now, it has already been stated that discharge occurs after time $t = kRC$; the frequency of discharge will be $1/kRC$, and the energy stored at the instant of discharge will be $\frac{1}{2} CV_s^2(1 - e^{-k})^2$. However, the power P_d drawn from the condenser by the discharge circuit (the product of the energy released at each discharge and the frequency or rate at which the energy is expended) is

$$P_d = \tfrac{1}{2} CV_s^2(1 - e^{-k})^2 \times \frac{1}{kRC} = \frac{V_s^2(1 - e^{-k})^2}{2kR} \quad .. \quad (3)$$

If eq. (3) is differentiated with respect to k and equated to zero, it is possible to arrive at the optimum period of the cycle.

$$\text{For maximum power} \quad .. \quad \frac{\mathrm{d}P_d}{\mathrm{d}k} = 0$$

$$\text{or} \quad \frac{V_s^2}{2R} \times \frac{\mathrm{d}}{\mathrm{d}k}\left[\frac{(1 - e^{-k})^2}{k}\right] = 0$$

Differentiation of this equation yields

$$e^k = 1 + 2k$$

This equation can be solved graphically to give k approximately equal to 1·3. Substitution of this optimum value of k gives $t = 1{\cdot}3\ RC$, and hence

$$v_c = 0{\cdot}73\ V_s$$

In other words, the optimum breakdown value of v_c is 0·73 V_s. If the condenser were discharged at a higher voltage, greater discharge energy would result, but this would be more than offset by a lower spark frequency and conversely, if discharge took place at a lower value, the advantage due to increased frequency would be negated by the smaller charge. Gap distance should be held to maintain this value, and this may be effected with a servomechanism type of electrode position control.

Considering further eq. (3), for discharge power, with the chosen value of $k = 1{\cdot}3$

$$P_d = \frac{V_s^2(1 - e^{-1{\cdot}3})^2}{2 \times 1{\cdot}3R} = 0{\cdot}21\ V_s^2/R \text{ [watts]} \quad .. \quad (4)$$

From consideration of eq. (4), it would appear that, for maximum discharge power and consequently maximum stock removal, it would be advantageous to increase supply voltage V_s and to reduce resistance R, both as far as possible.

Maintaining R constant, the discharge power becomes directly proportional to the square of the supply voltage, and a plot of stock removal with respect to supply voltage approximately bears out this power law in practice.

However, it must be borne in mind that the rating of the equipment will also obey this power law and consequently the problems of physical size, cost, and insulation must be taken into account. Also safety considerations must be borne in mind in the case of production equipment, since this high voltage will be impressed between the electrode and workpiece. A third and perhaps more influential factor is indicated by eq. (2) for the energy stored at discharge. The energy of each individual spark naturally determines its intensity and consequently the amount of metal removed. This in turn determines the resulting surface finish, which rapidly deteriorates with an increase in voltage. Consequently, the choice of voltage is essentially a compromise.

From eq. (4), if voltage V_s is fixed, P_dR is constant, and a practical plot of the relation between these two quantities is approximately hyperbolic. However, if the value of R is reduced excessively, a continuous arc discharge is set up, ruining the surface of the electrodes. A possible explanation is that the charging time constant RC is reduced to such an extent that, after a discharge, the voltage is built up on the condenser before the gap is sufficiently de-ionised. This explanation is confirmed by a similar effect experienced when a small time constant results from the use of a small condenser. Conversely, the larger the condenser selected, the more the resistance may be reduced before this condition of

arcing is set up. It appears, therefore, that there is a lower limit to the time constant which limits the spark frequency of this type of circuit. These limitations appear to be in the order of 10,000 sparks per second, or a charging time constant of about 100 μ sec.

It has been shown that the power expression is independent of capacity C and its variation would not, therefore, be expected to exercise any effect on stock removal. However, stock removal decreases at lower capacities and tends to be more constant at higher values. Perhaps this can be partially explained by the fact that, in practice, the spark frequency departs from the theoretical values computed with the lower values of time constant and capacity (Fig. 8). It is possible that this is due either to the discharge time, hitherto neglected, which is now of the same order as the charging time, or to the skin effect at the higher frequencies, which increases apparent resistance and consequently charging time.

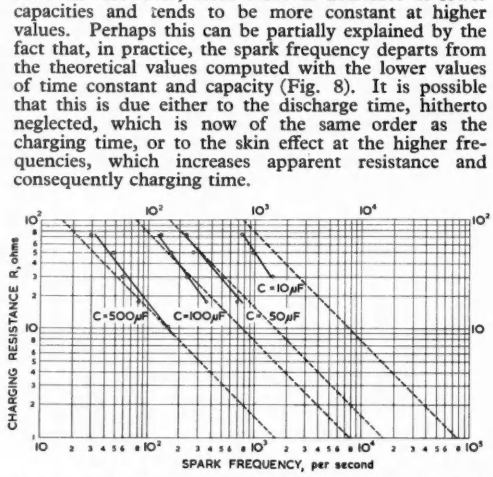


Fig. 8. **Comparison of theoretical and experimental spark frequencies.**

Frequency is plotted as a function of charging resistance R, with capacity C as a parameter. The experimental curves (dotted lines) have been computed from $F = 1/(kRC)$, with $k = 1 \cdot 3$ for optimum discharge power.

At very low capacities, the condition of arcing, previously menonetid, is set up and must be considered as a separate effect from that on the time constant.

Besides its influence on stock removal, capacitance has an important bearing on surface finish, in the same way as, but to a lesser degree than, supply voltage V_s; this is easily understood when recalling that the surface finish is dependent upon the energy released at each discharge, according to eq. (2).

The following is a summary of the various factors concerned :—

Supply Voltage V_s :—Stock removal increases with increasing supply voltage, but this involves a higher rating of equipment, stricter safety precautions, and a poorer surface finish. Usually, however, in standard equipment, voltage is variable over a small range only and consequently, insofar as the operator is concerned, choice of voltage is limited.

Resistance R :—A reduction in resistance increases stock removal, but excessive reduction leads to arcing.

Breakdown Voltage V_B :—This factor has an optimum value for a given supply voltage V_s and may be set to this value by servo-control. Variations in breakdown voltage have the same effect on surface finish as supply voltage, but breakdown voltage is usually variable only over a small range.

Capacity C :—Stock removal increases with increasing capacitance ; this, however, adversely affects the quality of surface finish and results in oversize holes.

It should be stressed, however, that the influence of the above parameters may sometimes be different in practice, and will also vary according to electrode and work materials. For a really satisfactory prediction of the influence of these parameters, it is necessary to make plots of their effects under the actual conditions in which machining is to be carried out.

New Method of Testing Spot Welds on Low-Alloy Steel

By P. JOUMAT. (From *Revue de la Soudure, Belgium*, Vol. 10, No. 2, 1954, pp. 100-104, 13 illustrations.)

A NEW method of testing spot welds on low-alloy steels has been developed after difficulties had occurred in the spot welding of new passenger coaches supplied to the French Railways (S.N.C.F.). These coaches are constructed of medium steel and are of box-type design, to reduce weight.

Low-alloy medium steels are weldable, their carbon content generally being not higher than 0·16%. The manganese content is fairly high (about 1·25%), and a small percentage of chromium is added to obtain a high U.T.S. (not less than about 24 tsi). These steels are only slightly tempered, but it has been found that, by suitable thermal and mechanical treatment of the welding spots, robust welded assemblies can be obtained.

This spot treatment can be effected with modern welding equipment operating with electronic controls which enable annealing and forging to be carried out under favourable conditions. However, the use of machines of this type has made it necessary to provide a simple test method giving rapid and reproducible test results. It has been found that the torsion-and-shear method is the most convenient for this purpose.

The test specimen is easily made and consists of two small square plates with sides of about 2½ in. in length and of the thickness used in the assembly considered. After cleaning the surfaces by sand or shot blasting, the plates are joined at their centre by the type of spot welding to be tested. The test itself is simple and consists of gripping one of the two plates in a vice while the other is subjected to a torsional stress, applied by means of a wrench, until rupture occurs. To facilitate gripping in the vice, the plates are arranged for welding with the sides of one plate at 45 deg. to those of the other, thus forming an eight-pointed star. To eliminate the use of a wrench, one of the plates can be constructed as a combined plate-and-lever specimen, cut integrally from a single piece of metal. The lever portion may be bent upwards slightly for easier handling.

The test should be carried out only after cooling of the welding spot in still air, and the torsion should be applied slowly and evenly. The fracture can be examined with the naked eye or preferably with a powerful magnifying glass. The test may be completed, if desired, by measuring the angle of torsion at which rupture takes place in the weld.

The criteria for a satisfactory weld have been found by experience to be as follows :—(a) The fracture should be in the plane of the junction ; (b) there should be no jagged protrusions of the metal ; (c) the diameter of the welded spot should not be less than the diameter of the electrode points, nor more than 20% greater ; (d) there should be no physical defects present, such as voids, blisters, inclusions, shrinkage cracks, etc. ; (e) the material torn off at the periphery of the spot should have a jagged, crown-like appearance.

The method thus requires no special test equipment and can be carried out in any workshop where spot welding is used. The consistently similar appearance of the weld fractures is the essential feature for periodic check tests. The method has also been applied successfully to other types of weldable steel, especially unalloyed mild steel, which gives fractures of somewhat different appearance, but whose features are nevertheless also easily identifiable.

For laboratory research, the test may be developed to include the determination of a diagram of torque plotted against the torsion angle, so as to permit a detailed study to be made of all factors affecting welding quality, and to simplify process control. Quality index numbers can be assigned to the results of resistance spot-welding operations by means of fracture tests of this type on specimens supplied for acceptance tests.

The Use of Low-Grade Fuels in Turbo-charged Diesel Engines

By C. Casci and F. Scirocco. (From *L'Ingegnere*, Vol. 28, No. 7, July 1954, pp. 757-767, 17 illustrations.)

The Franco Tosi Company, when developing a new, medium-speed, turbo-charged engine, considered that it would be of interest to carry out tests on this engine with various types of fuel, i.e., gas oil, diesel oil, and boiler fuel. These tests and the results and conclusions obtained therefrom are described in this article.

In recent years, engine manufacturers have devoted increased attention to low-grade fuels. The tendency is to use fuels of high specific weight, low cetane number, and high sulphur content. These heavy fuels frequently give rise to corrosion and to the formation of carbonaceous deposits.

Systematic tests on diesel engines running on these fuels have been carried out for many years and there are now many engines normally operating on heavy fuel. However, most of these are large, low-speed engines. Experience is more limited in the case of medium-size engines operating at medium speeds.

The Tosi Q-34 Engine with Büchi Turbo-Charger

Most of the tests here described were carried out on the six-cylinder Tosi Q-34 four-stroke, single-acting engine, the principal data of which are as follows:—

Bore, 310 mm; stroke, 450 mm.
Swept volume per cylinder, 23·95 litres.
Normal speed, 428 rpm.
Compression ratio, approximately 12·1:1.
Mean piston speed, 6·4 m/sec.

Fig. 1 shows a cross-section through the engine. The cylinder heads are provided with two inlet and two exhaust valves. The liners are intensively cooled by means of the Tosi cooling system. Light-alloy pistons are used.

The pressure-charging unit, built by Tosi under Büchi licence, comprises a single-stage centrifugal compressor driven by a single-stage exhaust gas turbine. The shaft carrying the radial compressor is an integral part of the turbine wheel. The compressor impeller is supported by bearings at the central and inner portions of the shaft, whereas the turbine rotor is overhung. A cavity for water circulation is provided in the stator space between the turbine and compressor; this ensures fairly intensive cooling and reduces the heat introduced during compression. To improve the charging efficiency of the engine, the compressed air is passed through a cooler before entering the cylinders.

The six cylinders discharge in pairs into three manifolds. The three exhaust ducts of these manifolds are arranged in spirals around the outer portions of the turbine and discharge into distributor passages which lead the gases to the turbine blades. After doing work in driving the turbine, the gases are led out into a "diffuser-ejector" (Fig. 2), divided into three sections corresponding to the three sectors of the turbine in which the gases produce work after emerging from the three exhaust manifolds.

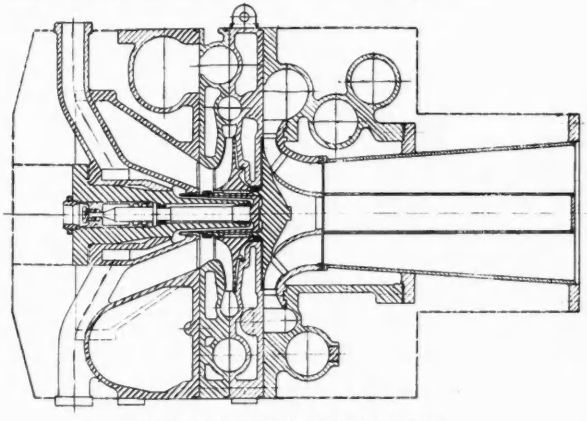


Fig. 2. **Cross-section of turbo-charger.**

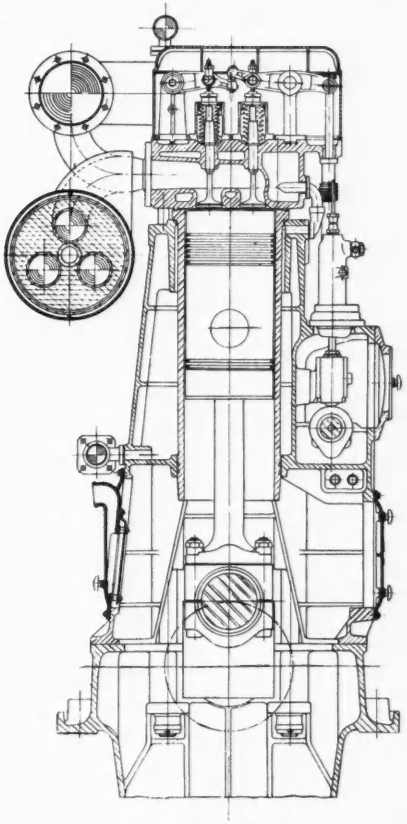


Fig. 1. **Cross-section of Q-34 engine.**

The inward-flow turbine used in the Q-34 engine is particularly suitable for supercharging systems. Under similar conditions, its efficiency is higher than that of the axial-flow turbine, so that it can absorb a greater amount of total heat for the same deflection of gas flow on the turbine blades.

The inward-flow turbine generally gives rise to a counter-pressure due to centrifugal force. It can be measured at the end of the exhaust stroke, but does not cause any disturbance in the exhaust process of the engine cycle. This counter-pressure is very small; for the Q-34 engine, at about 900 hp, it is estimated to be of the order of 0·09 kg/cm², whereas the pressure of the air delivered is 0·45 kg/cm². Moreover, this counter-

pressure is compensated by the fact that the diffuser of the turbine creates a sub-atmospheric pressure at the turbine outlet.

The diffuser-ejector has the following advantages :— (1) The diffusers recover part of the kinetic energy of the gas during the exhaust process and reduce the pressure on the outlet side of the turbine. This results in an increase in the enthalpy drop across the turbine and hence in its output. (2) The three diffusers have a common outlet at the turbine exit, which is designed in such a way that the depression obtained in one diffuser also affects the other two. This is of considerable importance for scavenging. It should be noted that the gases leaving a cylinder attain critical velocity soon after the opening of the exhaust valves, and that further improvement in scavenging can then be obtained only by means of the strong depression in the diffuser-ejector outlet. Pressure diagrams taken at the entry and exit of the turbine clearly illustrate these conditions.

Types of Fuels Tested

In the tests carried out on the Q-34 engine, three types of fuel were used, i.e., gas oil, diesel oil, and boiler fuel. The characteristics of these fuels are given in Table I.

Table I. Characteristics of Fuels Used.

	Gas Oil	Diesel Oil	Boiler Fuel	
			non-purified	purified
Specific gravity at 15° C	0·836	0·911	0·953	0·960
Viscosity (Engler) at 45° C	1·20	2·80	19·10	20·40
Impurities	trace	trace	trace	trace
Water [%]	trace	trace	trace	trace
Ash [%]	trace	trace	0·02	0·02
Sulphur [%]	0·85	1·67	3·12	3·05
Carbon residue (Conradson) %	0·10	1·90	8·50	9·10
Hydrogen [%]	13·52	12·18	11·65	11·72
Flash point [° C]	88	100	136	140
Calorific value ..gross	10,850	10,620	10,440	10,410
[kcal/kg] ..net	10,154	9997	9840	9820
Distillation at 250° C [%]	27	—	—	—
300° C [%]	70	22	4·5	4·2
350° C [%]	93	—	—	—
Cetane number	56	—	—	—

No special treatment was provided for the gas oil and diesel oil. The boiler fuel was passed through two De Laval-type purifiers in series. Before entering the first purifier, the boiler fuel was heated to 90-95° C and this temperature was also maintained at the entry to the second purifier by means of an intermediate reheater. After this treatment, the boiler fuel was passed directly into the service tank, in which it was suitably reheated. The deposits collected in the purifiers after 48 hours operation were measured and it was found that they amounted to about 0·04% of the boiler fuel treated.

Particular care was taken to ensure a very high degree of filtration of the fuel before it entered the injection pump.

Preliminary Tests on a Single-Cylinder Engine

A single-cylinder, non-pressure-charged, 4-stroke engine was used for a number of preliminary tests, before carrying out tests on the Q-34 engine. This single-cylinder engine has two inlet and two exhaust valves, other engine data being as follows :—Bore, 310 mm ; stroke, 405 mm ; swept volume of cylinder, 30·5 litres ; test speed, 500 rpm ; mean piston speed, 6·75 m/sec.

The tests on this engine, with the three fuels already mentioned, were carried out over a total period of about 60 hours at an ambient air temperature of 25-28° C and a barometric pressure of 738 mm Hg. The engine was lubricated with a detergent-type oil (SAE 40). Fig. 3 shows the results obtained, i.e., fuel consumption and gas temperatures at the cylinder-head outlet, plotted against horsepower and brake mean effective pressure.

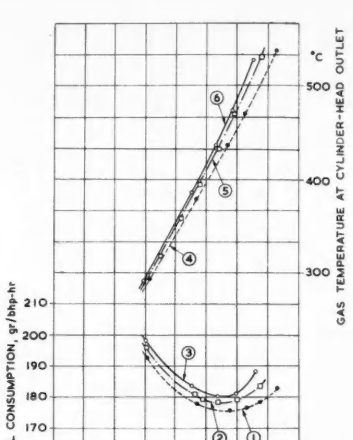


Fig. 3. **Results of preliminary tests on single-cylinder engine.**
(1) Fuel consumption, using gas oil.
(2) Fuel consumption, using diesel oil.
(3) Fuel consumption, using boiler fuel.
(4) Gas temperature at cylinder-head outlet, using gas oil.
(5) Gas temperature at cylinder head outlet, using diesel oil.
(6) Gas temperature at cylinder-head outlet, using boiler fuel.

The following points of interest may be noted :—

(1) The maximum permissible effective pressure of the engine for normal running conditions was reduced by changing from gas oil to diesel oil and boiler fuel, as follows :—

Gas oil, 7 kg/cm² ; diesel oil, 6·6 kg/cm² ; boiler fuel, 6·25 kg/cm². The exhaust gas temperatures at the cylinder-head outlet were 540° C with gas oil, 530° C with diesel oil, and 505° C with boiler fuel.

(2) Although fuel consumption increased, when changing from gas oil to diesel oil and boiler fuel, the total heat consumption, and hence engine efficiency, showed only slight variations.

Tests on the Pressure-Charged Engine

Tests to determine engine performance: The Q-34 engine with the Tosi-Büchi turbo-charger was coupled to a Froude hydraulic dynamometer. The arrangements for the tests included the following features :—

Lubrication of the valve gear was provided by means of an electrically driven auxiliary pump ; the SAE 30 oil used for this purpose was first filtered in a vane-type filter and then passed through a Winslow conditioning filter before entering the engine. The cylinders were lubricated with SAE 40 oil. Lubrication of the bearings of the turbo-charger rotor was ensured by a separate oil system, with an oil pump driven by the engine.

Cooling of the engine was by water supplied by an electrically-driven pump, the water being cooled in a cooling tower. The supply of fuel to the injection pumps was ensured by means of an electrically driven delivery pump, drawing oil from the service tank.

Fuel consumption was determined by weighing. Air-flow measurements at the turbo-charger inlet were carried out with a measuring orifice. Gas and air temperatures were measured by means of accurately calibrated thermocouples. All other temperature measurements (water, lubricating oil, and fuel) were made with precision-type mercury thermometers.

During the tests with the various types of fuel, barometric pressure was between 735 and 750 mm Hg and ambient temperature was 10 to 15° C. It should be noted that, in the tests with boiler fuel, both starting

and stopping were made on gas oil, the heavier fuel being used only when the engine was warmed up.

The curves for fuel consumption, exhaust-gas temperature at the cylinder-head outlet, and air pressure at the intake manifold, for the engine operating on gas oil, diesel oil, and boiler fuel, are shown in Fig. 4, from which it may be noted that :—

(1) The specific consumption of the engine operating on the three types of fuel tested shows minimum values over a fairly wide range, so that the engine can be run with good efficiency in all three cases from approximately 5·5 to 9·5 kg/cm² i.m.e.p.

(2) The fuel consumption per brake horsepower increases when passing from gas oil to diesel oil and boiler fuel, but this is mainly due to the corresponding decrease in calorific value. The engine efficiency, therefore, remains practically the same for all three types of fuel used.

(3) The exhaust gas temperature at the cylinder-head outlets remains practically constant for the three fuels at a constant value of i.m.e.p. From this it may be inferred that the combustion conditions are practically similar for the three fuels considered.

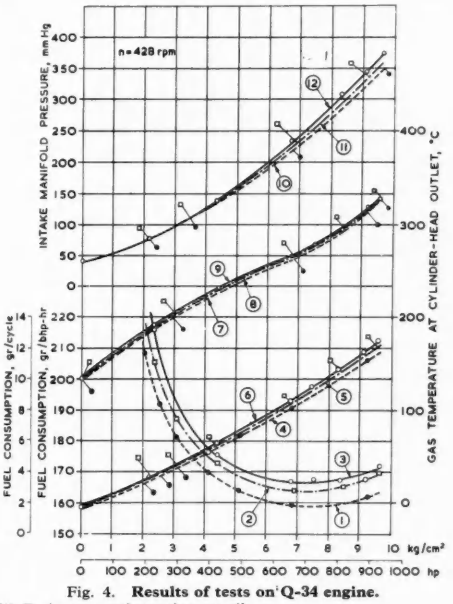


Fig. 4. **Results of tests on Q-34 engine.**

(1) Fuel consumption, using gas oil.
(2) Fuel consumption, using diesel oil.
(3) Fuel consumption, using boiler fuel.
(4) Fuel consumption per cycle, with gas oil.
(5) Fuel consumption per cycle, with diesel oil.
(6) Fuel consumption per cycle, with boiler fuel.
(7) Gas temperature at cylinder-head outlet, using gas oil.
(8) Gas temperature at cylinder-head outlet, using diesel oil.
(9) Gas temperature at cylinder-head outlet, using boiler fuel.
(10) Intake-manifold pressure, using gas oil.
(11) Intake manifold pressure, using diesel oil.
(12) Intake manifold pressure, using boiler fuel.

Figs. 5 and 6 show performance curves of the Tosi-Büchi charger system, plotted against engine power, with the engine operating on boiler fuel.

The efficiency of the compressor (Fig. 6) was evaluated from the ratio of the adiabatic work and the effective work done in compression, determined by means of measurements of the rise in air temperature between the inlet and outlet of the compressor.

The cooling of the charging air is of considerable importance for engine efficiency. To assess this effect, tests were carried out with the engine running on diesel oil at approximately 950 bhp and varying the temperature of the intake air. The figures obtained are given in Table II, in which t_i = intake air temperature [° C], p_i = intake air pressure [kg/cm²], v_i = specific volume of intake air [m³/kg], t_e = exhaust gas temperature, and q_s = specific fuel consumption [gr/bhp-hr].

TABLE II. TESTS WITH ENGINE RUNNING ON DIESEL OIL AT 950 BHP.

t_i	p_i	v_i	t_e	q_s
25·3	1·506	0·58	309	166·9
49·2	1·522	0·62	345	171·9

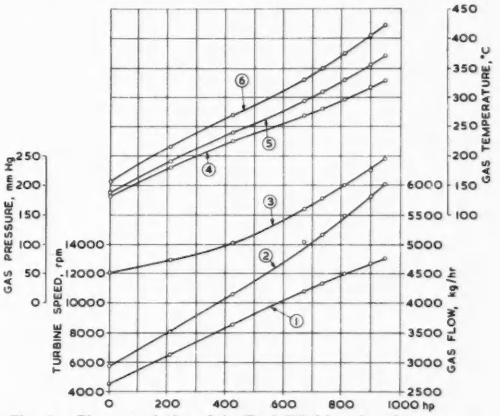


Fig. 5. **Characteristics of the Tosi-Büchi turbo-charger, as a function of engine power, using boiler fuel.**

(1) Turbine speed.
(2) Gas flow.
(3) Mean gas pressure in turbine intake manifold.
(4) Mean gas temperature at cylinder-head outlet.
(5) Gas temperature at turbine outlet.
(6) Mean gas temperature in turbine intake manifold.

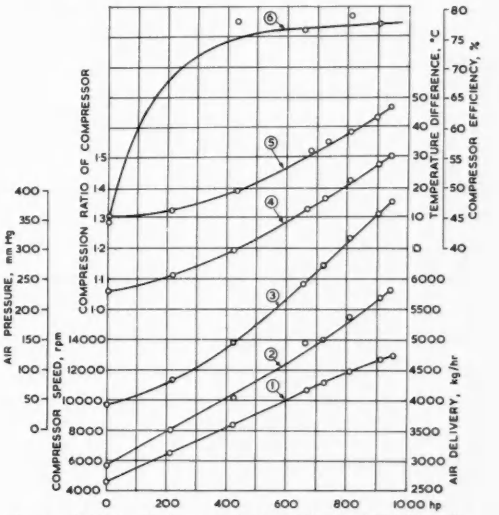


Fig. 6. **Additional characteristics of the Tosi-Büchi turbo-charger, as a function of engine power, using boiler fuel.**

(1) Compressor speed.
(2) Air delivery.
(3) Air pressure at cooler inlet.
(4) Compression ratio of compressor.
(5) Temperature between compressor inlet and outlet.
(6) Compressor efficiency.

From the measurements taken on the Tosi-Büchi turbo-charger it was noted that :—

(1) The air delivered to the engine is at an appreciable pressure and thus ensures charging of the cylinders with a considerable amount of air.

(2) The air delivery pressure is higher than that of the gases down to very low engine loads (160 bhp. approximately), thereby indicating the high efficiency of the charging system.

(3) The mean gas temperature measured at the turbine inlet has fairly moderate values, reaching a maximum of 420° C when the engine is running at 9·7 kg/cm² i.m.e.p., corresponding to about 940 bhp.

Tests to determine deposit formation: In order to obtain data on the formation of carbonaceous deposits in the engine, the following tests were carried out with diesel oil and boiler fuel :—

(a) The engine was run on diesel oil for 48 hours at 428 rpm, at a brake mean effective pressure of 9·8 kg/cm², corresponding to 950 bhp. At the end of the tests, the cylinder heads, the pistons, and the turbo-charger were dismantled, and it was found that the formation of carbonaceous deposits had occurred only to a limited extent. The piston rings were quite free in their grooves. The carbonaceous deposits formed during these tests were extracted and weighed. The test results are given in detail in Table III.

(b) The engine was run on boiler fuel at 428 rpm, at 9·25 kg/cm² b.m.e.p., corresponding to a power output of 900 bhp. The tests were carried out in two periods, of 48 hours and 40 hours, respectively.

The main results were obtained during the first period of testing (48 hours). At the end of this period, after removing the cylinder heads and pistons, and stripping the pressure-charger system, it was found that the quantity of carbonaceous deposits was slightly higher than in the tests with diesel oil. The piston rings were absolutely free in their grooves. The tests results for this 48-hr period are also given in Table III.

TABLE III. COMPARISON OF TEST RESULTS.

	DIESEL OIL	BOILER FUEL
No. of running hours	48	48
Fuel consumption [gr/bhp-hr]	168-170	169–172
Temperature of fuel at entry of engine [° C]	—	65–80
Mean gas temperature at cylinder outlet [° C]	328–339	310–325
Mean gas temperature in manifold at turbine inlet [° C]	416–430	395–418
Mean gas temperature at turbine outlet [° C]	358–378	346–350
Air temperature at intake manifold [° C]	33–39	23–28
Pressure in intake manifold [mm Hg]	356–358	346–350
Mean temperature of cooling water for air cooling [° C]	22–27	22–28
Turbine speed [rpm]	12,800–12,870	12,800
Engine speed [rpm]	428	428
Weights [gr] of carbonaceous deposits:		
In injector nozzles	trace	0·35*
On outer piston surfaces (between piston ring No. 1 and piston crown)†	1·95	2·10
On piston crown†	1·65	2·75
On cylinder heads and valve seats‡	2·55	4·52

*mean of six nozzles ; †mean of six pistons ; ‡mean of six cylinder heads.

The second series of tests on boiler fuel extended over a total of 40 hours, also at 900 bhp. The tests were made to obtain basic data on the formation of carbonaceous deposits as a function of running time. The procedure used was as follows :—

(1) The engine was run continuously for 8 hours, after which the cylinder heads and pistons of cylinders 1 and 2 were removed and the carbonaceous deposits formed on these parts were extracted.

(2) The engine was run for another 8 hours, and carbonaceous deposits were then removed from cylinders 3 and 4.

(3) Finally, the engine was run continuously for 24 hours. At the end of this series of tests (total duration, 40 hours), all the cylinders were stripped and deposits were removed from all cylinder heads and pistons. The results obtained are given in Table IV.

TABLE IV. WEIGHTS OF CARBONACEOUS DEPOSITS.

No. of running hours	Cylinders inspected	Mean value of carbonaceous deposits [gr]			
		Nozzles	Piston skirt above ring No. 1	Piston crown	Cylinder head and valve seats
8	1 & 2	0·25	0·90	0·52	2·10
16	3 & 4	0·40	1·35	1·12	2·12
24	3 & 4	0·35	1·60	2·40	3·80
32	1 & 2	0·40	1·85	2·55	4·14
40	5 & 6	0·40	2·03	2·60	4·70

The deposition of carbonaceous residues is a question of equilibrium between the formation of deposits and their elimination, as a result of combustion and the dissolving power of the lubricating oil. From Table IV, it is seen that (1) the weights of deposits are fairly low, and (2) the deposits, after a first period of formation, tend to increase only very slightly, so that it may be concluded that there should be no difficulties due to deposit formation when the engine is operated on boiler fuel, even for extensive periods of continuous running.

Engine wear: In view of the limited number of hours of the tests, the wear measurements were not sufficiently extensive to provide reliable information. The authors refrain, therefore, from giving data which would not be of practical importance, since the minimum duration for obtaining observations of this kind is in the neighbourhood of 1000 to 2000 hours.

CONCLUSIONS

The tests carried out on the Tosi Q-34 engine lead to the following conclusions :—

(1) The efficiency of the engine (i.e., its consumption in kcal/bhp-hr) does not vary appreciably when changing from gas oil to diesel oil or boiler fuel.

(2) The satisfactory results obtained with the engine running on boiler fuel are considered to be attributable in the first place to the supercharging obtained with the Tosi-Büchi turbo-charger. The charger enables combustion to take place with considerable excess air, since it permits a considerable quantity of air to be introduced into the cylinders at low temperature and high density, and thus practically eliminates the disadvantages of delayed combustion occurring with heavy fuels.

Comparison of Figs. 3 and 4 (relating to the naturally aspirated engine and the pressure-charged engine respectively) is of particular interest. Whereas in Fig. 3 the exhaust-gas temperatures at the cylinder-head exits are noticeably increased when using diesel oil or boiler fuel instead of gas oil, in Fig. 4 the three curves for the various fuels nearly coincide, thus showing that the negative qualities of combustion of boiler fuel are practically eliminated by means of the supercharging.

Particular importance is attributed also to the special design of the Tosi cooling system for the liners and to the adoption of light-alloy pistons, which give improved heat transmission. These features provide more favourable conditions for the detergent action of the oil on the piston and the piston rings.

It may thus be concluded that four-stroke engines of medium size and medium running speeds can be run under favourable conditions on boiler fuel, using adequate supercharging and highly efficient cooling of the liners.

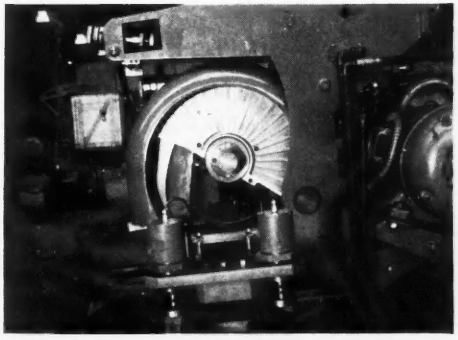
New Materials, Processes and Equipment

ABRASIVE-WHEEL CUT-OFF MACHINES

A range of abrasive-wheel cut-off machines for the rapid, continuous production cutting of bars, tubes, and sections, is announced by L. J. H. Ballinger Ltd., of Woodchester, Stroud, Gloucestershire.

Outstanding features of these machines, which are hydraulically operated and fully automatic, include positive hydraulic single or multiple bar feed, visual load indication, and wheel guides for control of side flutter. Their most outstanding features are, however, the new wet-cutting system employed, with an eccentric head and water-cooled wheel guard.

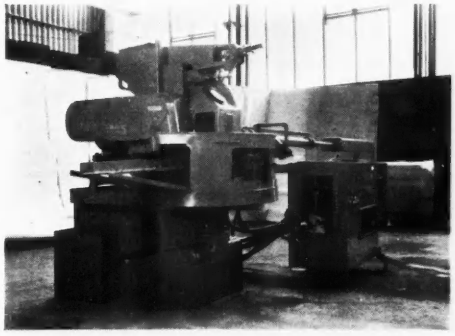
The eccentric head, shown in the illustration below, uses a rotary cutting disc, mounted on a spindle with an overriding planetary motion from a separate drive having a slightly different speed of rotation. This has the effect of converting the disc to a virtually single-point cutting tool, with a different curvature to the path of the cut, reducing the area of contact between the disc and the work. Owing to the extremely slight difference in relative speed of the planetary motion and the main drive, this point on the periphery of the disc will make a considerable number of revolutions before it again makes contact with the workpiece. In the meantime, other successive points on the periphery of the cutting disc are performing a like cutting motion at each revolution, the wheel, however, wearing uniformly on the periphery. During this time, the disc is continually being passed through a chamber in which coolant is retained, absorbing heat from the cutting disc. This planetary action and reduced area of contact, in the case of an abrasive wheel or disc, enables the grits to cut rapidly successive scallops of metal, without unduly tearing them from their bond medium, followed by a stream of coolant which washes away chips and loose grits.



The coolant guard encloses a sector of the wheel, and is made in two halves, one fixed and the other readily removable for wheel replacement. Coolant from a motorised circulating pump is supplied to both halves of the guard, the interior consisting of radial grooves tapering in the direction of rotation of the wheel. The fine clearance between the surfaces of the guard and the cutting wheel, coupled with the high speed of rotation, builds up sufficient water pressure to cool the wheel effectively, thus extending its life.

A damper controls the actual contact pressure of the cutting disc in relation to the work. Since the workpiece is contacted during only a small portion of each revolution of the disc, the planetary motion tends to push the cutting head back against the infeed, and this is resisted to a greater or lesser extent by this damping device. Adjustment of the damper enables the rate of infeed to be controlled by the cutting qualities of the abrasive disc and not by a fixed rate of feed.

Cut-off wheels are of the rubber-bonded type, specially produced in various grades to suit operating conditions and materials. A feature is the triangular-shaped centre hole, ensuring a positive drive, eliminating the scoring of the spindle associated with round-hole wheels, due to wheel slip.



The automatic, hydraulically operated reciprocating feed is positive in action and is fitted with a grooved extension bar for cutting to predetermined length. The grooves are graduated every 2 inches, final increments being obtained by a micrometer sleeve. Maximum feed length, according to the model, is either 36 in. or 18 in. per stroke.

Illustrated above is the Type " A " model manufactured by Ballingers.

UNIVERSAL MILLING ATTACHMENT

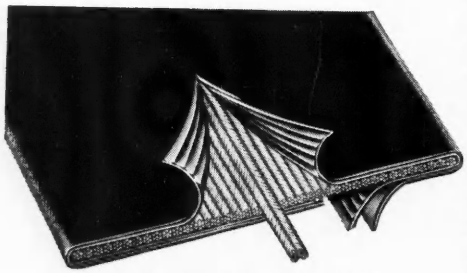
The " UFK " universal milling attachment, manufactured in Austria and marketed in Great Britain by Herbert Bennett Ltd., of London, E.C.2, is a motorised insert cutter head for the rapid and accurate milling of threads, keyways, etc., and of plane faces in lathes and on milling machines.

The principle which enables this comparatively small attachment to mill away a considerable amount of material in a short time is that of intermittent fly-cutting. The tools are cooled by air on the idle part of their circuit, whereas the workpiece heats up sufficiently to facilitate impact cutting. Absence of vibration, essential for hard-tipped fly-cutting, has been achieved by rugged and compact design and simplicity of driving arrangements. Inertia is imparted to the cutters by the flywheel effect of the 9-lb cutter head, which incorporates a two-step V-pulley, thereby preventing slowing down of the tools on impact.

The rotating insert cutter head has four axial and four radial grooves, the former for plane milling of end faces or long workpieces held stationary in a lathe, and the latter for milling all types of threads and for milling keyways and flutes and grooves generally. Tool-holder mandrels can replace the insert cutter head for milling to fine limits, in one operation, fine and coarse internal threads with hard-tipped cutters of suitable profile. With this type of mandrel, a flywheel, to replace the flywheel action of the cutter head, can be supplied.

The standard version, with two-step V-pulleys, provides for two fly-cutting speeds for steel machining.

WHAT IS YOUR TRANSMISSION BELT PROBLEM?



GOODYEAR ENDLESS CORD BELTS

For high-speed, small-pulley machinery. Goodyear Endless Cord Belts incorporate a patented balanced construction of load-carrying cords and cover. Their H.P. capacity is one third greater than ordinary belts of equal thickness.

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These belts are built to stand up to high starting torques, stalls and shock loads. Continuously wound, high tensile cords ensure great strength and resilience. Designed for use on hard working, industrial multi-V drives.

heavy loads

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mildew

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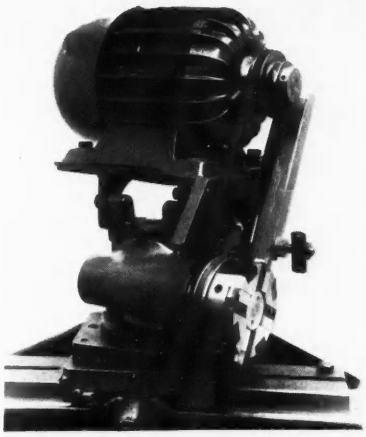
YOU GET LONGER WEAR from Goodyear flat transmission and 'V' belts. Firstly, because they are basically constructed to withstand far longer the strain of continual, vigorous service. Secondly, because there is a Goodyear belt that is ideally suited to *your* conditions of service; whatever problems you have — heavy shock loads, intricate drives, severe flexing — belting by Goodyear will help you overcome them. Ask our technical staff to help you decide which is the best Goodyear 'V' or flat transmission belting for your purpose.

GOODYEAR

INDUSTRIAL RUBBER PRODUCTS

TRANSMISSION BELTING · V-BELTS · HOSE · CONVEYOR BELTING



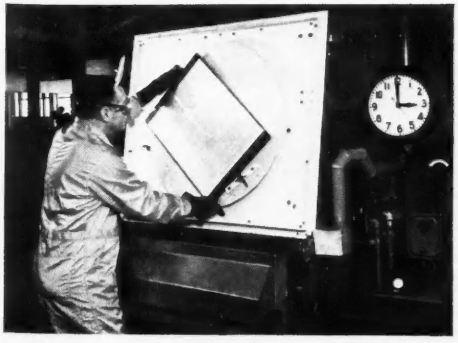
A version with augmented drive equipment is also available, and has a range of five speeds. An extensive range of swivel provides for all requirements likely to occur in engineering practice. The baseplate caters for 360 deg. of swivel in the horizontal plane, and is so dimensioned as to facilitate assembly on the cross-slide of most lathes with 4 in. or more centre height. In the case of milling machines, the attachment can be screwed to the vertical column and tilted to suit the work in hand, or it can be set up on the table.

CHEMICAL METHOD OF MAKING MAGNESIUM PRINTING PLATES

A new chemical method of making magnesium printing plates has been developed by the Dow Chemical Company, U.S.A. It is claimed that the new method will result in the production of high-quality plates much more rapidly and economically than by conventional means formerly in use.

Specifically, it is in the etching process that the improvements have been made. The developments consist of the application of a unique etching solution to a magnesium-alloy plate in a specially designed machine. The plates prepared by the new process are etched cleanly and sharply in as little as one-tenth of the time formerly required.

It is believed that this etching development can also be applied to several other printing processes, some of them new. One of these is the " dry offset " or photo-engraved offset, which relies on an etched relief plate. Letterpress printing should also be facilitated by the new etching process.

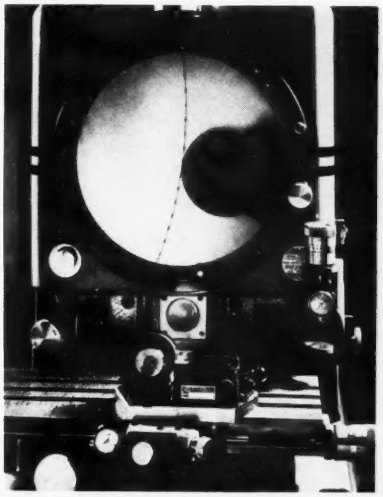


OPTICAL GAUGING OF CAMS

A NEW and effective method of checking the entire contours of cams quickly and accurately has recently been developed by Optical Gaging Products, Inc., of Rochester, N.Y.

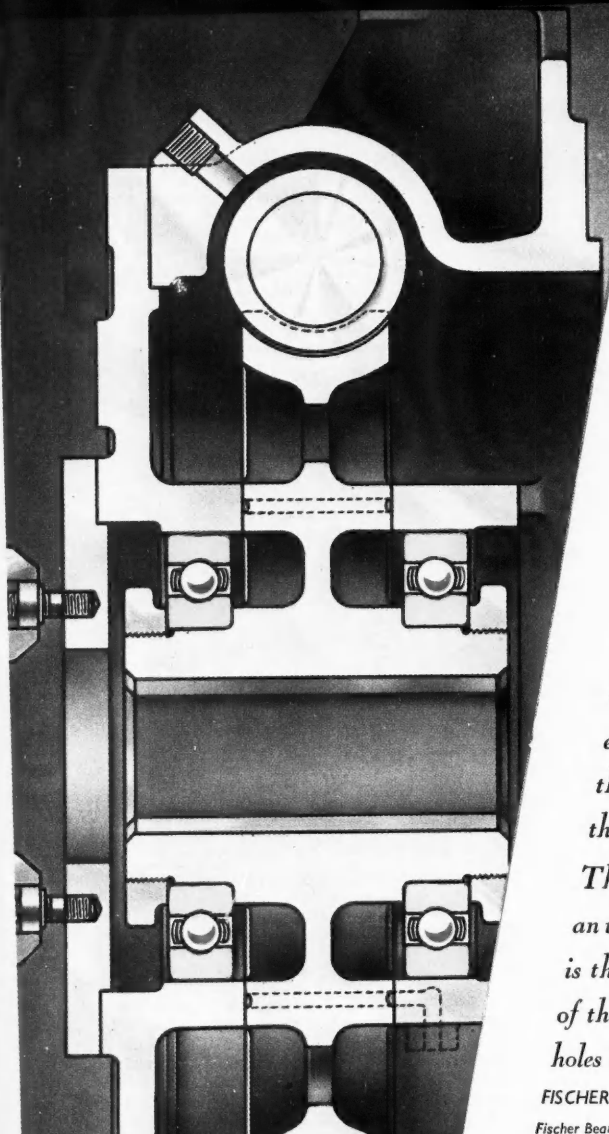
Using the intense light from the surface illuminator of a Kodak contour projector, this optical gauging method permits inspection of cams mounted as they will be held in assembly.

Basically, the method is simple :—The cam is mounted on an arbor which may be turned by hand. Turning the cam actuates a follower which carries with it an indicator ball. How closely the indicator ball follows tolerance lines, also rotating with the cam, may be readily watched on the projector screen at a large magnification, as shown below.



The cam to be checked is mounted on an arbor of the staging fixture, shown in the lower foreground of the illustration. The staging fixture is fitted with an adjustable Y-type yoke carrying two followers, one of which is a precision hardened-steel ball, which is spring-loaded to follow the contour of the cam itself, while the other is an indicator ball which faithfully duplicates the motion of the cam follower. The cam to be checked is mounted on a common axis with a glass reticle. The cam is on the operator's end of the axis. The reticle is mounted on the end of the axis facing the projector. The motion of the reticle throughout inspection procedure is identical with that of the cam. The reticle is an accurate, full-scale reproduction on glass of the contour and tolerance lines, as specified on the cam drawing. The reticle may be quickly replaced. Tolerance and contour revision may be incorporated in replacement reticles.

In considering how the image of the indicator ball gets to the screen, it should be noted that the light source is the surface illuminator itself. A feature of the Kodak contour projector is the effective location of the surface illuminator on the optical axis, within the cabinet of the projector. Incorporated in the staging fixture, on the operator's side of the reticle, is a mirror (see illustration overleaf) facing the contour projector. Thus, the light from the surface illuminator passes through the glass reticle to this mirror. The light is then reflected back through the glass, past the black tolerance lines of the reticle, into the projector's optical system, and so to the viewing screen. The images of the tolerance lines and indicator ball are thus projected onto the screen at any selected magnification. Initially, the cam and the reticle are



Turbine turning gear

The drawing shows an interesting detail, a turning gear for a Parsons' Marine turbine. The worm and wheel are always in mesh and the worm can be driven by an electric motor. When needed, for the inspection of the main machinery, the worm wheel is coupled (by a removable shaft engaging in the squared bore of the worm wheel) to a pinion engaging the main gearing.

The bearings are F.B.C., an unusual feature of the design is the plain-bearing side-location of the worm wheel. The transverse holes in the wheel are for lubricant.

FISCHER BEARINGS CO. LTD., WOLVERHAMPTON

Fischer Bearings Co. Ltd., and Timken-Fischer Stockists Ltd., Birmingham, are both subsidiaries of British Timken Ltd.

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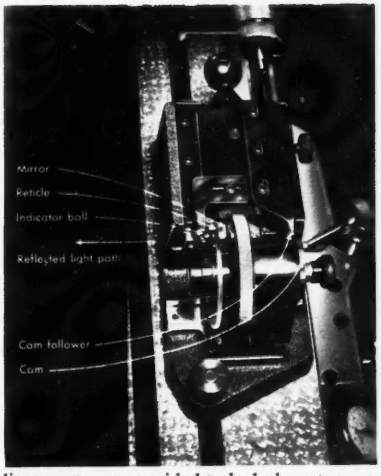
brought into complete co-ordination, insofar as angular and radial location of a starting check-point is concerned. This is accomplished by making adjustments so that the image of the indicator ball is tangential to the image of a " set-line," when the set-master provides a V-notch for positive location of a cam-follower ball at an initial reference point specified on the part drawing.



Adjustments are provided to lock the set-up securely in position. The master cam is then replaced with an actual cam, and the checking procedure may proceed for all points around the periphery of the cam. The spring-loaded cam follower traces the contour of the cam, while the indicator ball on the reticle side, as already stated, accurately follows its position in relation to the master reticle projected on the screen.

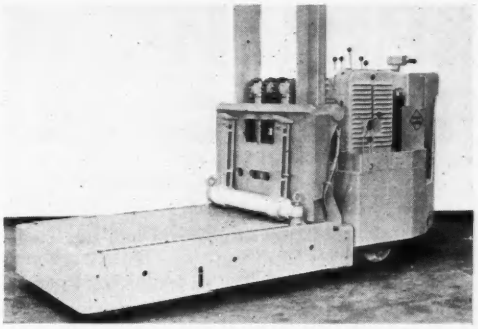
The tolerances of cam contours are often called out at only specified angular intervals. In addition, the total tolerance for any one check point may vary from the total tolerance of another check point. These variations in tolerance along the contour of the cam are accurately reproduced on the reticle glass. The cam contour is drawn through all the variable tolerances at all locations. Hence, every point along the contour receives an immediate visual check. Thus, not 720 points at one-half degree intervals along the contour, but an infinite number of points, are checked in this manner. Any pits, blemishes, tool marks, or scratches of any nature, which may throw intermediate points out of tolerance, are indicated positively on the viewing screen.

It is claimed that, whereas inspection of cams, with tolerances as close as 0·0005 in., previously required 13 hours per cam by an experienced inspector, the optical gauging method has reduced inspection of the entire contour to 40 seconds, with an inexperienced operator. Furthermore, it is claimed that, with the new method, there is no wear problem, not are there any difficult adjustments to make, as vulnerability to handling is entirely eliminated.

DIE PULLERS

A new range of die pullers, with capacities ranging from 10,000 to 100,000 pounds, designed for use in automotive, aircraft, and other stamping and forging plants using heavy presses, has been announced by The Elwell-Parker Electric Company, of Cleveland, Ohio.

Features of the new models include hydraulic lift and hydraulic push-off units, which permit " inching " action. Hydraulic valves need only very slight cracking to permit accurate positioning of the platform and aligning of the die in the press. Each of the two pusher arms can be operated independently or simultaneously, to permit accurate manoeuvring of the die into position.



If necessary, a die can be pushed off diagonally, even when the platform is not square with the press bed, thus saving normal time while manoeuvring the truck.

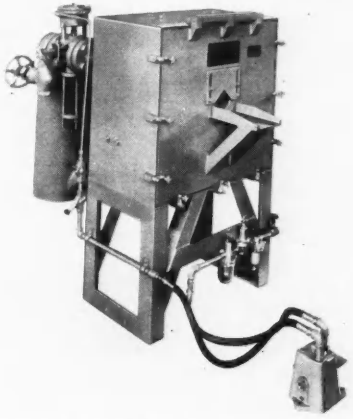
The upright design, using hydraulic lift, permits unobstructed forward vision for the operator. There are no lift chains, no cables between the uprights, and no crosshead at the top of the uprights. Hydraulic power steering on all wheels permits effortless, accurate handling of the trucks.

It is also pointed out that, with modern low press beds, these trucks provide the lowest possible platform without any sacrifice in capacity, because the die-pulling mechanism is located alongside the platform, intead of under it, as in the case of conventional trucks.

BILLET DESCALING CABINET

The Elmes billet descaling cabinet, manufactured by American Steel Foundries, Elmes Engineering Division, Cincinnati, Ohio, is a highly efficient unit, specially adapted to situations where furnace and forging presses are located close to one another, where a variety of pieces is to be handled, and where only part of the billet is to be descaled.

The spray ring is fitted with four easily accessible spray nozzles, which completely encircle the billet. The unit, which is of welded-steel construction, can be supplied with the necessary operating controls for use with an existing accumulator system, or as a complete " package " unit, including the accumulator system.



In addition to this hand-feed type, fully automatic descalers can also be supplied, with gravity- or power-driven conveyor heads. In these models, which can be either pit-mounted or floor-mounted, the spray ring has six spray nozzles, and the roller conveyor is arranged to withstand extreme temperatures.

PHILIPS INDUSTRIAL HIGH FREQUENCY HEATING EQUIPMENT

Philips Electrical Limited manufacture a wide range of High Frequency Generators and allied equipment for Induction and Dielectric heating applications, ranging, in the case of Induction heating, from the large 160 kW. generator down to one of only 2½ kW. Philips extensive experience in many branches of industry has been utilized in the design and construction of these generators. Three popular models are described below:

F.280 (160 kW) Generator :

Max. Power output at terminals	160 kW	Cont
Max. Power required from Mains	300	kVA
Power Factor	0.9	
Mains Supply Voltage — 380/440v. 3-ph	50	cycles
Nominal Frequency	200	kc/s

F.50 (25 kW) Generator :

Max. Power at Terminals	25	kW
Max. Power required from Mains	50	kVA
Power Factor	0.9	
Mains Supply Voltage — 380/440v. 3-ph	50	cycles
Nominal Operating Frequency	350	kc/s

F.5 (2½ kW) Generator :

Max. Power at Terminals	2½	kW
Max. Power required from Mains	5	kVA
Power Factor	.85	
Nominal Operating Frequency	520	kc/s

Other Philips Generators available are :—

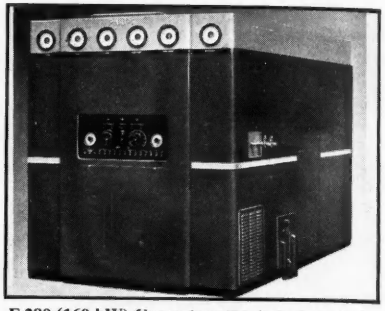
F.150 (80 kW) Induction Heating Generator
F.100 (50 kW) Induction Heating Generator
F.26 (14 kW) Induction Heating Generator
F.18 (10 kW) Induction Heating Generator
F.13 (6 kW) Induction Heating Generator
DF.1500 (750 W) Dielectric Heating Generator
DF.6 (3 kW) Dielectric Heating Generator.
All the above generators conform to BSS. 1799.

PHILIPS also manufacture a range of allied equipment including Work Inductors and Concentrators, Flexible Water Cooled H.F. Leads, H.F. Change-over Switches, and Melting Units. For full information, please write to the address below.

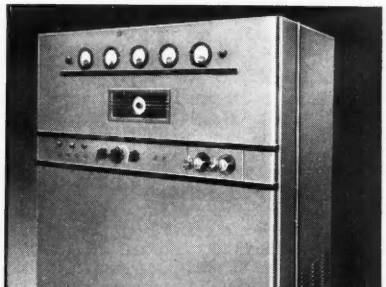
PHILIPS ELECTRICAL LTD

INDUSTRIAL GROUP, CENTURY HOUSE, SHAFTESBURY AVE., LONDON, W.C.2

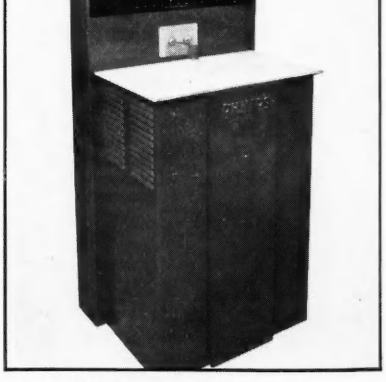
ARC & RESISTANCE WELDING & EQUIPMENT, H.F. GENERATORS, MAGNETIC FILTERS, ELECTRONIC INSTRUMENTS, ETC.



F.280 (160 kW) Generator: This is the largest valve-driven electronic heating generator in Europe, and its design incorporates the most modern features.



F.50 (25 kW) Generator: A medium-sized equipment which is in constant demand in many industries.



F.5 (2½ kW) Generator: Compact and extremely versatile, this low-powered equipment has proved increasingly popular.

(HF271)

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

ELECTRONICS

Industrial Metal Detectors.

By T. G. CHARLES. (From *ASEA Journal, Sweden*, Volume 27, No. 4, 1954, pp. 55-64, 13 illustrations.)

AFTER discussing existing metal detectors and their drawbacks, this article describes a new type of simple and sensitive detector, specially intended to fulfil industrial requirements.

The new detector is characterised by simplicity of design and operation. When used directly for detecting metal, only two controls are required. One of these is for reducing sensitivity, if this is found to be too great for any particular application. The other control varies the time for which the relay is operated after reception of a signal. Apart from these two controls, which are normally adjusted after installation, no adjustments whatsoever are necessary. The amplifier and power unit are standard items, intended for use with a wide range of coils, to suit nearly all applications. When considering any new application, the only factors to be taken into consideration are the size and shape of the coil and the optimum frequency to be used.

The detector is thus very suitable for a wide range of applications, among which must be mentioned the detection of tramp metal in magnetic iron ore and the grading of ores and coal. Preliminary investigations have shown that coal produces a considerable reduction in the output voltage of the instrument when it passes over the measuring coil, whereas slate, stone, and other refuse have no measurable effect. Thus, the detector, in combination with a recently developed machine for feeding forward single pieces of ore of approximately the same size, opens up the possibility of completely automatic cleaning of coal, thereby eliminating the need for the present costly method of hand sorting.

In the case of iron ore, it is normal to grade the ore into three qualities, i.e., high-grade, medium-grade, and low-grade. The system developed consists of a belt feeding single pieces of ore over the measuring coil. The change in output voltage can be made to operate relays, actuating mechanical deflectors which pass the pieces to suitable bins, according to their iron content.

Experiments have shown that the system is equally applicable to the grading of copper ore. In this case, it should be noted that copper ore causes a reduction in output voltage. Additional experiments have shown that metal contained in slag can also be sorted in a similar way. This is important in the case of expensive metals, such as nickel, chromium, and stainless steel.

FATIGUE OF METALS

The Effect of Grinding on the Fatigue Strength of Steels.

By D. N. CLEDWYN-DAVIES. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, August 1954, 11 pages, 12 illustrations.)

THIS paper describes an investigation to determine the effects of cylindrical grinding on the fatigue strength of a range of steels, i.e., a nickel-chromium-molybdenum alloy steel, hardened and tempered to give a nominal ultimate stress of 80 tons per sq in.; the same steel, hardened and tempered to give a nominal ultimate stress of 62 tons per sq in. (Vibrac V30); a 0·6% carbon steel (45 tons per sq in.); and a 0·1% carbon steel (27 tons per sq in.).

Fatigue tests were carried out in a rotating-beam machine giving uniform bending moment, and the limiting fatigue ratios (endurance limit/nominal ultimate stress) of 0·538, 0·545, 0·420, and 0·550 were determined for turned and longitudinally-polished specimens of the Ni-Cr-Mo steel (80 tons per sq in.), Vibrac V30, 0·6% carbon, and 0·1% carbon steels.

Preliminary tests on Vibrac V30 showed that there was a small reduction (about 4%) in the limiting fatigue ratio, due to grinding. Further experimental work, however, showed that there was no intrinsic reduction in the fatigue strength for this material. Fatigue tests on ground specimens, stress-relieved *in vacuo* after grinding, indicated that the reduction found in preliminary tests was not due to surface tensile stresses, and it is suggested that the reduction was due to poor grinding technique, causing burning of part of the surface at the bottom of the 3-in. transition radius. Some specimens of Vibrac V30 were ground by two external laboratories and tested by the author. The fatigue strength of these two batches of specimens was not completely determined, owing to the small number of specimens available. In one case, the grinding was very uniformly carried out, but indicated a reduction in the fatigue strength of at least 8 to 10%. The other batch of specimens also showed a reduction in fatigue strength, but no definite conclusions can be drawn, owing to the small number of tests carried out and the large scatter of results obtained.

There was no reduction in the fatigue strength due to grinding the 80-tsi steel, Vibrac V30, and 0·6% carbon steel, although a small reduction (about 3½%) was obtained with the 0·1% carbon steel. This may possibly have been caused by undetected burning of the surface during grinding, as the same speed, feed, and wheel were used for all four materials.

It is concluded that grinding does not cause a reduction in the fatigue strength of the materials tested, provided that grinding is carried out carefully and under good grinding conditions. The degree of care required to avoid deleterious effects, however, is such that it does not seem advisable to advocate the grinding of fatigue specimens generally, unless preliminary fatigue tests have been carried out to determine the true state of the ground surface. Finally, the grinding of parts that are to be subjected to high fluctuating stresses should be avoided, owing to the uncertain state of the "production-ground" surface.

IRON AND STEEL

Flame Characteristics and Melting Rates in Steelmaking.

By E. J. BURTON. (From a paper presented at a meeting of *The West of Scotland Iron and Steel Institute, Glasgow*, September 10, 1954, 10 pages, 3 illustrations.)

STEELMAKERS would probably rank open-hearth fuels in increasing order as mixed gas, producer gas, coke-oven gas, and heavy fuel oil. Producer gas gives a flame which is useful in all stages of the open-hearth process; its chief drawback is its low flame temperature. Coke-oven gas is particularly efficient at cutting down scrap, but is inefficient for preventing foam formation. Heavy fuel oil is particularly useful for its versatility, the quan-

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tity of atomising agent giving a control on the flame length and the rate of combustion.

The design and application of a simple efficient burner by B.I.S.R.A. has given an opportunity of elucidating the effects of steam/oil ratio and coke-oven gas on works furnaces, without upsetting the production routine. The burner not only provides a means of improving combustion efficiency but also is itself, through its potential effect on productivity and fuel economy and its standardisation of burner practice, a useful research tool.

In this paper, steelworks practice and current research are briefly contrasted. The use of the B.I.S.R.A. burner should give an opportunity of elucidating relationship between melting rates and steam/oil ratio, for oil firing and gas pressure for coke-oven gas firing. A comparison is being made between coke-oven gas and oil firing for the charging period, and a pyrometer for measuring gas temperatures is described.

The data so far available do not make it possible to present a logical, closely argued account of fuel usage in the open-hearth, but a blend of empirical reasoning and theoretical analysis leads to the following recommendations for maximum productivity :—

(1) In the charging period, a high-momentum, high-temperature flame is required.
(2) In the melting period, especially after the addition of hot metal, a high-momentum, highly luminous flame is required to transfer the heat through the slag layer.
(3) In the refining period, the cheapest fuel may be used, although some luminosity may be required.
(4) In the use of coke-oven gas, the supply pressure should be sufficiently high to give a short flame. Consideration should be given to steam as a means of shortening the flame, if the pressure cannot be increased above 15 in. w.g.
(5) The air preheat temperature should be measured at regular intervals with a protected, refractory suction pyrometer.

Spectrophotometric Determination of Silicon in Steel and Cast Iron.

By P. ENGHAG. (From *Jernkontorets Annaler, Sweden*, Vol. 138, No. 7, 1954, pp. 404-413, 6 illustrations.)

IN the spectrophotometric method described by Hill and by Arnfelt, Freyschuss, and Rönnholm, the original silicon content in steel and cast iron is deduced from the extinction of the yellow solution of silicomolybdic acid produced. The present investigation is concerned with the influence of temperature on the rate of formation and the stability of this coloured solution. Whereas the reaction at room temperature is so slow as to require some twenty minutes for the extinction to attain its maximum value, this process is completed in less than two minutes at 100° C. However, at this elevated temperature the transformation of the strongly coloured silicomolybdic acid to the weakly coloured form, β-modification turning into α-modification, according to Strickland, also takes place at a considerably increased rate. This results in a bleaching effect after prolonged heating, particularly noticeable with high silicon contents. For this reason, the holding time at 100° C should be maintained fairly closely at the prescribed value, i.e., $1{\cdot}5 \pm 0{\cdot}5$ minutes, at least when the solution is high in silicon.

The influence of temperature on polymerisation of silicic acid, when the sample is dissolved in nitric acid, has also been studied on samples of cast iron. It transpires that improved reproducibility is obtained when the sample is boiled in the acid directly over the hot plate, as compared with dissolution in acid at controlled temperatures between 70° C and 100° C, maintained by a water bath.

Results of the application of the modified method are given in tables.

OPEN-HEARTH FURNACE PRACTICE

The Use of Various Fuels in the Open-Hearth Furnace.

By W. B. WRIGHT. (From a paper presented at a meeting of *The West of Scotland Iron and Steel Institute, Glasgow*, September 10, 1954, 11 pages.)

ALTHOUGH many variables enter into the steelmaking process, such as furnace design, metallurgical load, type of scrap available, cold or hot metal charging, and the type of product, the logic of events in the use of various types of fuels during the last 10 to 15 years has demonstrated the great advantage of certain fuels over others in their ability to increase rate of heat transfer to the bath.

From the point of view of overall combustion efficiency, it may be assumed that any furnace is capable of burning fuel at some maximum rate. Fuel used either above or below this rate results in impaired efficiency. Assuming this maximum rate to be adhered to, then the fuel consumption per ton of steel depends upon the output.

The all-important factor in this consideration of heat transfer is flame characteristic. It is necessary to supply a given quantity of heat to the furnace, this being a function of the calorific value of the fuel, but it is equally important in the open-hearth process to have the correct flame quality at the different stages of the melting process. Heat transfer in the open-hearth process takes place by radiation, by convection, and, when charging, by direct contact with the scrap. Many theoretical workers have held the view that most of the heat transfer in the open-hearth process was by radiation. However, some of these investigators have recently modified this view as a result of certain practical work which has been achieved at several steel plants, particularly in those furnaces fired by coke-oven gas alone.

Industrial flames may be divided into two classes, i.e., those emitting a low radiant energy and those emitting a high radiant energy. Solids raised above the temperature of their surroundings radiate on all wavelengths, whereas gases do not. If the intensity of radiation for burning gases is plotted against wavelength, it is found that heat is radiated or absorbed between certain wavelengths, and the wave-bands are of appreciable breadth only in gases with three or more atoms to the molecule, e.g., H_2O vapour, CO_2, SO_2, and the hydrocarbons. Gases such as N_2, O_2, CO, and H_2 have little ability to radiate.

In this paper, the desired flame characteristics are considered and the following fuels discussed :— Producer gas ; mixtures of blast-furnace and coke-oven gas, oil, pitch and creosote. Test results are given on a furnace fired with a mixture of coke-oven gas and oil through a B.I.S.R.A. burner. The final output of the furnace was found to be substantially increased.

PLASTICS

The Use of Epoxy Resins for Laminated Tooling.

By J. DELMONTE. (From *Materials & Methods, U.S.A.*, Vol. 40, No. 2, August 1954, pp. 93-95, 6 illustrations.)

EPOXY resins have rapidly taken their place in the field of plastics tooling. In many tooling applications for the aircraft and automotive industries, epoxy resins have superseded other types of bonding media in glass-fibre laminated structures. The two most important reasons for this change are the low shrinkage of epoxy resins and their outstanding adhesion to glass fibres.

The adhesion of these resins to glass, metals, and ceramics has been recognised for some time, and numerous general-purpose adhesives have been developed to make use of this property. In laminated plastics tooling, this results in nigh interlaminar bond strengths and longer tool life. In addition to the specific properties which set the epoxy resins apart, they also have the other advantages of reinforced plastics struc-

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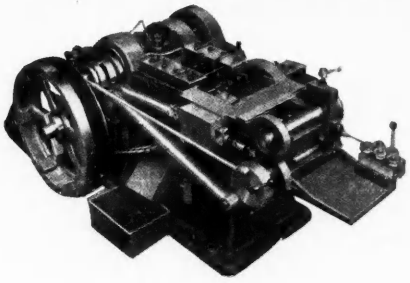

Model	Thread Diameter approx.	Max. Length	Production per hour	H.P. Reqd.	Weight lb.
F53	5/32" to 5/16"	7/16" to 2 3/8"	3,000 to 5,000, according to size	10	9,200
F54	2 mm to 5/8"	5/16" to 1 3/4"	5,400 to 6,000	5	5,950
F55	5/16" to 1/2"	13/16" to 4 3/4"	2,400 to 3,000	15	22,000

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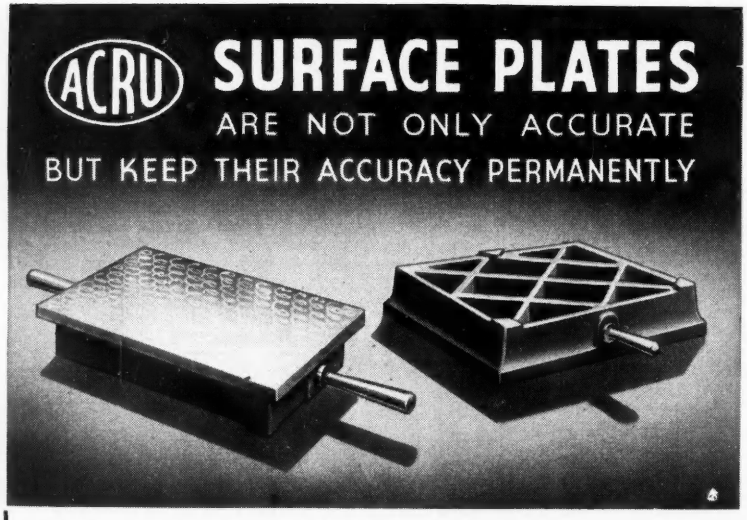

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tures, inasmuch as they are light in weight, durable, and strong. A major part of the question of whether to use these resins for laminated tooling must therefore be answered by balancing the particular requirements of each job against the increased cost of the material, and by considering the many types of epoxy resins available.

Laminated epoxy resins have been extended into the field of draw dies and some drop-hammer dies, as they appear to display the wear and durability essential to these operations. Furthermore, their life expectancy and usefulness for some operations are better than those available with other forms of plastics tooling. Where it may be necessary, for purposes of economy, to employ less costly materials, polyesters, phenolics, and others have been used for back-up purposes behind the working face of epoxy laminating resin.

Although these resins have a high degree of dimensional stability, localised stiffening ribs should be included in the tool design, when large contoured sections are to be reproduced. These ribs may be of metal or plastic tubing, or of honeycomb cores, if lightness in weight is desired. The epoxy resin itself will secure the reinforcing member firmly to the overall structure.

The major limitation in the use of room-temperature-curing epoxy resins is that the highest heat-distortion point of these resins is to-date about 180° to 200° F, above which point their physical properties deteriorate rapidly. Furthermore, if careful control is not exercised during the addition of the hardener and during the lay-up of the resin and glass fibres, the qualities of the laminate will be inadequate for tooling purposes.

PUMPS

An Experimental and Theoretical Investigation of Two-Dimensional Centrifugal-Pump Impellers.

By A. J. ACOSTA. (From *Transactions of the ASME, U.S.A.*, Vol. 76, No. 5, July 1954, pp. 749-763, 21 illustrations.)

AN experimental and theoretical investigation of a series of two-dimensional centrifugal pump impellers has been made in an effort to determine the usefulness of the potential theory for the description of flow. Computed values of the head developed and the pressure distribution on the vane surfaces are compared with measurements taken on logarithmic-spiral impellers with two, four, and six vanes.

The results of these measurements were found to agree fairly well with predicted values, when the flow conditions at the inlet of the vane system were favourable At flow rates near shock-free entry, large deviations were observed, and these could be traced back to non-uniformity in the inlet flow, arising from the abrupt inlet turn. The fact that agreement between the potential-flow calculations and experiments is as good as it is for flow rates much less than shockless, where pressure discontinuities still occur on the vane-inlet edges, is considered promising. Consequently, it would seem reasonable to suppose that, if a highly uniform inlet flow were supplied to the impeller, better agreement over a wider range of flow rates would result.

The theory, as it now stands, appears to be useful for design over certain limited rates of flow. Application to wide ranges of operating conditions is still restricted, as the inlet turn introduces many unknown factors.

THERMODYNAMICS

Application of the Similarity Theory on Radiation in Furnaces.

By C.-H. YHLAND. (From *Acta Polytecnica, Sweden*, Physics and Applied Mathematics Series, Vol. 2, No. 8, 1953, 31 pages, 6 illustrations.)

THE radiation from a given volume of gas in a furnace can be calculated fairly easily, because the absorption coefficients of the main components, i.e., CO_2 and H_2O, are well known. If the shape of the volume of gas in question is known, the emissivity and the heat exchange by radiation can be calculated. This, however, is based on the condition that the composition of the gas is known and is uniform. In the regions where combustion takes place, the composition of the gases is generally not known and varies from place to place in the flame. Furthermore, the radiation of a luminous flame is emitted not only by CO_2 and H_2O but also by small carbon particles present in the flame. These carbon particles are responsible for a considerable part of the radiation. Their existence was discovered long ago and the order of magnitude of their size has been determined in some cases. The calculation of the heat radiation from a luminous flame in a furnace thus presents some very difficult and complex problems.

In this paper, the equation of radiative equilibrium is established and discussed with regard to the principle of similarity. In the first instance, all the radiating elements are assumed to be " grey." For practical purposes, the equations of equilibrium for the radiation and absorbing medium and for the walls are deduced separately. The suspension of carbon particles is treated as a gas with an absorption coefficient α. This is an approximation, because the carbon particles are large compared with the molecules, but the approximation appears to be permissible.

The dimensionless quantities are deduced from the general equation of equilibrium with the energy equation in a form containing the interaction of the radiation energy. An example of plotting experimental values in terms of the dimensionless quantities is given. The number of experiments available, however, is insufficient to permit any definite conclusions to be made.

WELDING

The Significance of the Tension Test for Spot Welds.

By E. R. FUNK. (From *The Welding Journal, U.S.A.*, Vol. 33, No. 7, July 1954, pp. 363s-365s, 6 illustrations.)

A TENSILE-SHEAR test has been the most common test for spot-weld quality. However, it has been recognised that such a test is not completely discriminating and that it is not, by itself, a satisfactory criterion of spot-weld quality. This has been evident in one case where spots of satisfactory tensile-shear strength have been made which broke during subsequent shop handling. In this case, a tension test of a spot was performed and gave very low values. A change in welding settings gave shear values still meeting the required specifications and also produced spots of much higher tensile strength. No fracture during subsequent fabricating was found when the improved settings were used.

The commonly used jigs for testing the " crossed-strip " single-spot weld in tension do not give uniform tension loading in the weld. Pure tension requires that no bending whatever of the strips be permitted. This condition can be met only by an infinitely stiff sheet. In some preliminary experiments this stiffness condition was approximated by bonding spot-welded titanium sheets to 1-in. aluminium blocks by epon resin. When these spots were pulled in tension, the load reached 1600 lb, at which point the epon resin fractured. In the " crossed-strip " tension tests, similar spot welds fractured at loads of the order of 300 lb. This demonstrated conclusively that a spot can support in pure tension a load several times that normally measured by conventional tension tests.

In this article, the large effect of geometry of the test strip and the modulus of elasticity is pointed out, and it is shown why tension results have such wide scatter and why so many anomalies are encountered in tension-shear ratios. Furthermore, it is concluded that a fixture cannot be designed which accurately duplicates in a large test specimen the stress distribution occurring at the edge of the spot-weld nugget during tension testing.

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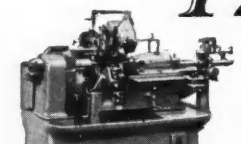

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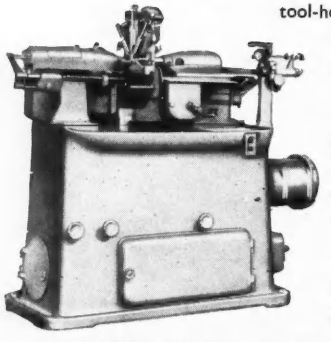

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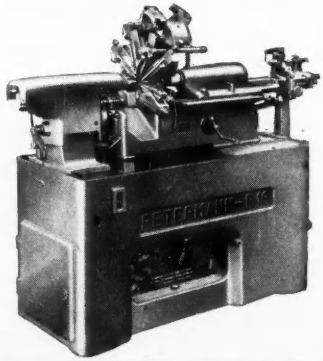

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A Review of Italian Machine Tools

By Dott. Ing. L. Beltrami.

A comprehensive review of the Italian machine-tool industry is naturally beyond the scope of an article of this nature. For reasons of space, therefore, this review is confined to descriptions of a relatively small number of machines exhibited by Italian manufacturers at the Fourth European Machine Tool Exhibition, Milan. It is hoped, however, that even this limited selection will be adequate to show the outstanding progress made by the Italian machine-tool industry in recent years.

The **Officine Rino Berardi,** of Brescia, are exhibiting several versions of their machines for multi-spindle drilling. These are built in four sizes and consist of a base carrying amply dimensioned ways for the drill head. A hydraulic control cylinder is mounted inside the base, while safety micro-switches, which, by means of appropriate dogs, actuate electric cut-outs, are mounted externally. The drilling-spindle carrier is provided with T-slots and reference marks for easy mounting of the drilling spindles.

As shown in Fig. 1, the multiple drill head consists of a massive casting, on which the dynamically balanced electric motor is mounted, provision being made for adjusting belt tension. The drive is transmitted by means of pulleys to the gearbox, which is fitted with as many individually adjustable drive shafts as there are drill spindles. Each drill spindle may have one, two, or three speeds, according to the type of gearbox provided. The drill spindles are of various types and sizes, according to requirements, and may be mounted either in supports with radially and angularly adjustable arms or in rigid supports, to suit the shape of the work. In all cases, they are axially adjustable, to allow for different drill lengths.

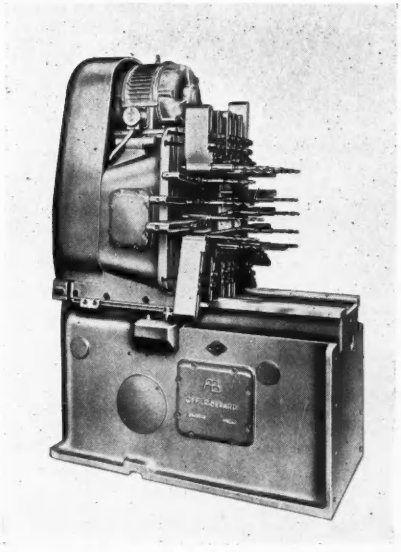


Fig. 1.

The hydraulic equipment is generally housed inside the base, but may be located at a suitable point away from the machine. This consists of a set of two Vickers pumps, one of which is a constant-delivery, high-capacity pump, operating at moderate pressure and serving all rapid motions and any auxiliary work, such as indexing, clamping, etc.; the other is a low-capacity pump, with variable delivery at high pressure, and serves the working feeds. The rate of feed is governed by the variation in pump delivery.

The pressure supplied by the pump is directly proportional to the load required, so that variation of the load entails only slight speed variations. When the load required by the tools exceeds the preset pressure, risk of damage is prevented by automatic rapid return of the head. Feed movement terminates similarly, so that, when the adjustable dog on the head contacts the micro-switch, rapid return takes place as a result of increased pump pressure. The stop is thus a positive one and considerable pressure can be obtained. This stop can, if required, operate a delayed-action device which retards the return, allowing a dwell of from 3 to 15 seconds. Various working cycles can be effected by means of relays actuated by remote-control switches operated by the micro-switches in contact with appropriate dogs. The cycles are easily preset by sliding these dogs in their guides. Various working cycles can thus be set for each drill head, and they are easily interchangeable.

The following is an example of a cycle in drilling deep holes :—Rapid approach, working feed varying from 3 to 30 seconds, rapid return to starting position, immediate rapid approach to within 1 mm of the point reached by the drill in the previous motion, second feed motion, second rapid return and repetition of the approach, and so on, down to the bottom of the hole, when final rapid return and automatic cut-out occur.

Tapping cycles can also be carried out and these, like all others, can be effected automatically by push-button. Once started, the cycle proceeds automatically, unless an overload occurs, but all stages of the cycle can be operated singly by means of the appropriate push-button—an extremely useful feature in setting up.

The firm of **Caser,** of Pavia, is showing radial drilling machines, whose productive capacity has been increased by several new features, such as the special mounting of the rigid main spindle, which is carried in a precision roller bearing at the end of the Morse taper, in order to reduce chatter to a minimum and to increase drilling capacity.

Speed changes are effected by means of devices specially designed to provide rapid, centralised control. Pre-selection equipment reduces idle time to a minimum and enables the most suitable speeds to be selected even for very short runs. All change gears are provided with a double friction clutch, which makes the machine particularly suitable for tapping operations. The feed control has a selector and is operated by a single hand-wheel, located in the centre of the head. The feed mechanism includes a safety clutch, which protects the machine against overloading under abnormal operating conditions.

A notable feature is the arm-locking mechanism, in which the arm holder is locked on the column and releases automatically only when the control for raising and lowering the arm is operated. In the small models, FR1 and FR7, locking of the head and arm swivel is controlled by independent hand levers, but in the large models, FR9 (Fig. 2) and FR10, it is operated by a motor actuated by two push-buttons located in the centre of the traverse wheel of the head. The arm is supported by a safety device which prevents it from falling in case of failure or excessive wear of the normal lifting mechanism.

The new 1250-mm radial drill, model FR10, is fitted with a change-speed gear which provides 15 speeds, from 29 to 1700 rpm, and is controlled by a pre-selector of the same type as on other Caser radial drilling

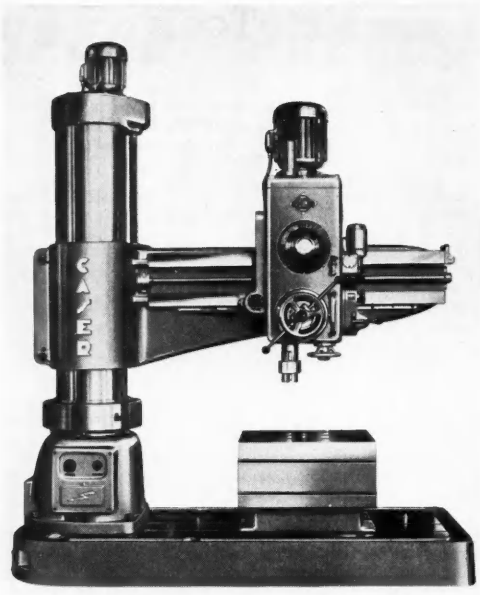


Fig. 2.

machines. The eight feed rates are controlled, as in the other machines, by a selector, in conjunction with a lever which selects from two feed ranges. Locking of the arm on the column is effected by the lifting motor; locking of the swivel and of the saddle is effected by a push-button control operating a self-braking motor. The drilling capacity of this machine in steel is up to 50 to 60 mm in diameter.

The **Officine Alfieri Maserati,** of Modena, are showing their latest models of milling machines, one of which, the U4, is illustrated in Fig. 3. These new machines

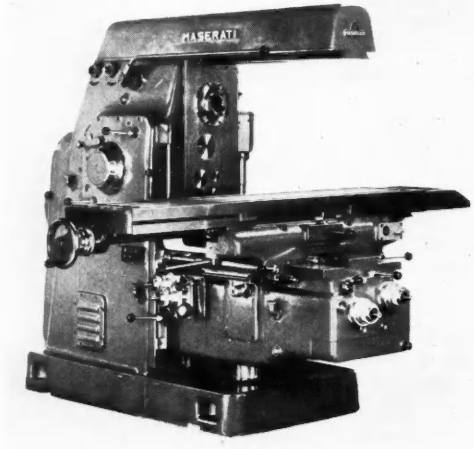


Fig. 3.

have been designed for maximum productive capacity by means of rapid, safe, and simple controls, and a minimum of idle time. As compared with previous models, they are more robust and show improvements as regards the driving mechanism, the selection and finish of materials used in their construction, and lubrication.

Care has been taken to ensure convenient location of the operating levers for the various feeds, simplicity of the automatic feed and spindle-speed controls, and smooth engagement and positive action of the spindle brake. All features, whether mechanical, hydraulic, or electrical, have been designed for maximum operational safety.

Giuseppe Minganti & Co., of Bologna, are exhibiting a wide range of machines, which, though based on earlier standard models, embody important modifications, resulting in considerably increased productive capacity.

In addition to their turret lathe, model 1A/80-100, which is a semi-automatic machine, with automatic selection of spindle speeds and feeds, they are exhibiting their automatic turret lathe, model 50E, which is derived from their smaller model 40/E, illustrated in Fig. 4, and is designed for a semi-automatic normal cycle and a fully automatic cycle when required, the change from one type of cycle to the other being effected instantaneously by means of a selector switch. In this lathe, the bed and the head are cast in one piece and the bed ways are of special surface-hardened steel.

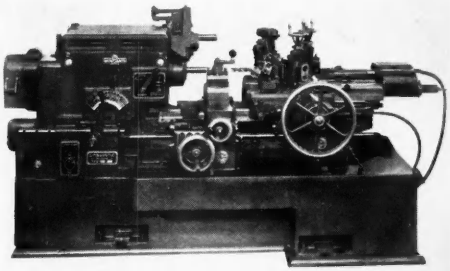


Fig. 4.

The spindle is driven by means of V-belts from an electric motor located in the base, this motor being of the pole-changing type. Of the eight speeds available, four are obtained by mechanical reduction through electromagnetic clutches and the other four by direct engagement. The feed change box is located on the left end of the lathe, drive being transmitted by means of a worm gear. Feed rates are varied automatically in response to the spindle speeds. The hexagon turret has a hydraulic rapid feed and a mechanical working feed, with automatic hydraulic indexing.

The cycle of the hexagon turret is as follows:—

(1) Hydraulic rapid feed; (2) working feed; (3) mechanical disengagement of feed and dwell; (4) hydraulic rapid return; (5) slowing down, and indexing and locking of turret. The preset automatic cycle is achieved by the synchronisation of spindle speeds and feeds with the indexing of the turret. Speeds and feeds are selected on a control panel mounted on the headstock.

The Minganti vertical milling machine, model FVM 4-5 (Fig. 5), already in normal production, has undergone considerable modification as regards the speed-change mechanism of the head, the electro-

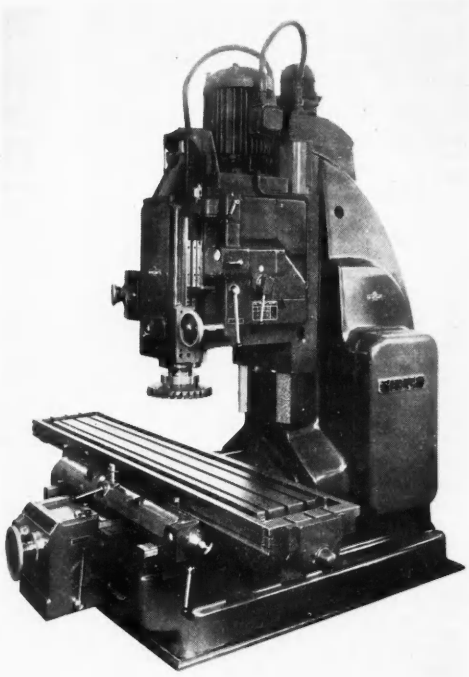


Fig. 5

hydraulic system having been replaced by a multiple-disc electromagnetic clutch, permitting extremely rapid and simple operation. The 24 spindle speeds are divided into a high and a low range, each of 12 speeds. Selection within either range is instantaneous and can be effected with the machine in operation. Changes from one range

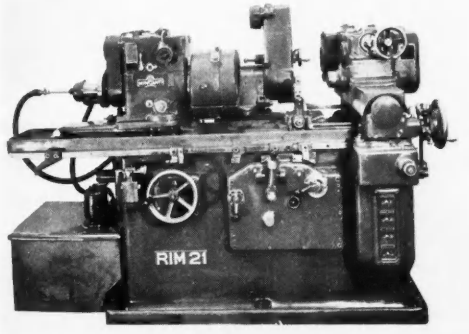


Fig. 6

to another are effected by a single lever and instantaneous engagement is ensured.

The Minganti internal grinding machine, model RIM 21-A, is based on the standard RIM 21 (Fig. 6), which has been converted for fully automatic operation. The three phases of the cycle—roughing, dressing of the grinding wheel, and finishing—have been made automatic by special electro-hydraulic equipment. The cam actuating the feed of the grinding-wheel spindle carries electrical contacts which serve to operate the hydraulic controls governing the entire automatic cycle. The operator's task is confined to pressing a button to start the machine, to turning a handwheel to bring the periphery of the grinding wheel into contact with the work to be ground, and to loading.

Oerlikon Italiana, of Milan, are exhibiting milling machines with massive, robust frames, 24 feeds, ample table working surface, spindle and feed braking, fully automatic lubrication of moving parts, provision for copying attachments, and simplification of electrical equipment.

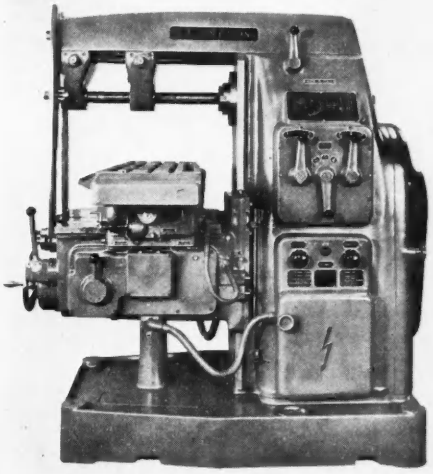


Fig. 7

In one of their automatic-cycle horizontal milling machines (Fig. 7), the six automatic cycles available are set by means of a four-position electric selector, while a fifth position enables the machine to be controlled manually by means of a single operating lever. The last two of the six cycles are continuous and permit the use of so-called reciprocal or pendulum milling. Backlash compensation on the table screw provides for two-directional milling.

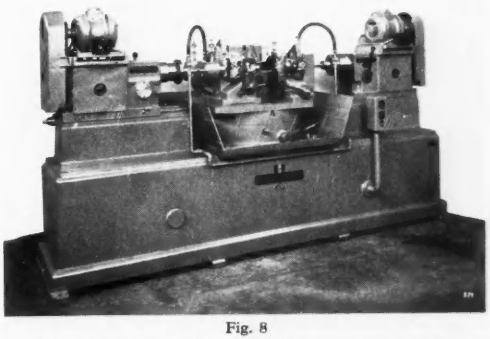


Fig. 8

The company is also exhibiting a newly designed milling machine, which, with various attachments, will meet a variety of technical requirements. This machine is also controlled by a single lever, and can be supplied

in several versions with different types of automatic control.

Another exhibit is a special machine for the mass production of certain components, an example of which is shown in Fig. 8. This is composed of units which are adapted for multiple drilling, facing, turning, etc. The work is held in special fixtures and the table moves pneumatically to the appropriate positions, according to the operation to be carried out. These positions are determined by a fixed stop with micrometer adjustment and a safety device permits the operation to be carried out only if positioning is perfect ; if not, the machine will not start. This system eliminates scrap arising through imperfect positioning.

In addition to their 16-speed, double-column vertical boring mill, model TV2150, **Ezio Pensotti,** of Busto Arsizio, are showing a single-column vertical boring mill of their new Series N 1100 (Fig. 9), which has a maximum capacity of 1200 mm, 16 table speeds, and a 30-hp motor ; also exhibited is model N 1550, with a capacity of 1550 mm, 16 table speeds, and a 40-hp motor.

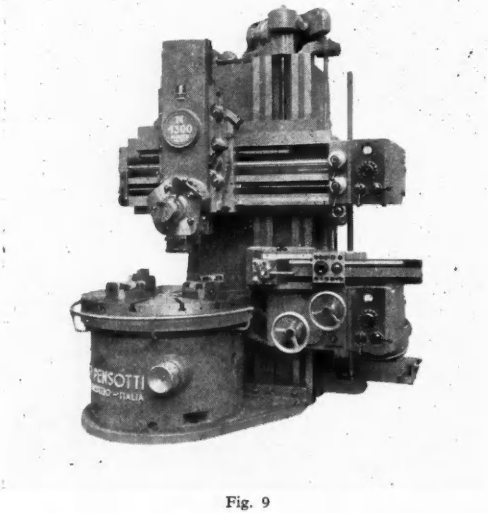


Fig. 9

These machines present considerable improvements as compared with previous models, including table-speed control by means of selector-actuated electro-magnetic friction clutches, which engage the gears for the selected speed, with the advantage that table speed can be varied during operation. Other improvements include direct-reading feed indicators and feed selection by means of a single lever, provision for mounting tools for the most varied operations, and end limit stops for mass production.

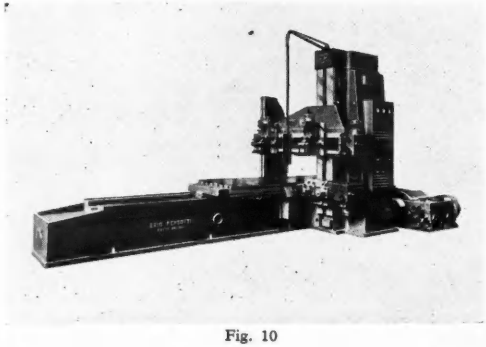


Fig. 10

In addition to their single-column planing machine, model PK 100 (Fig. 10), with a capacity of 3000 × 1000 mm, a double-column planing machine, model PWL 200 (Fig. 10a), with a capacity of 6000 mm × 2000 mm, is being exhibited. This is controlled by a Ward-Leonard set, with table speeds varying both for the forward and return traverse from 7·5 to 75 m/min.

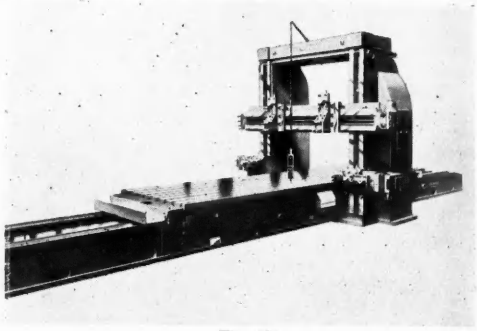


Fig. 10a

The ways of these planing machines are made of plastic materials specially chosen to reduce bed-way wear. All controls are centralised on a pendant switch-panel, to facilitate operation. These planing machines can be adapted for milling and grinding operations. Appropriate reduction gear for such operations is supplied, if required.

While **Tovaglieri,** of Busto Arsizio, are showing their range of TMRN rapid production lathes, their sister company, **"Duplomatic,"** is exhibiting hydraulic copying attachments which they have recently produced for vertical milling machines (Fig. 11). This new equipment has a dual hydraulic control linked in such a way as to deal with nearly all angles and to ensure at all of them a substantially constant feed rate along the profile.

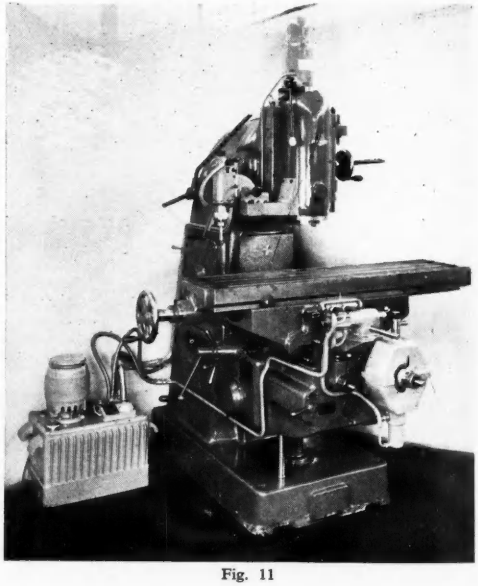


Fig. 11

This attachment can also be mounted on a horizontal milling machine.

A " contouring " attachment for milling machines, designed to produce cams, etc. is also being exhibited, as well as hydraulic apparatus for converting " line-by-line " copy-milling into area copy-milling.

The firm of **Cima,** of Bologna, is exhibiting a gear generator (Fig. 12) of excellent design and workmanship. In this machine, great rigidity combines with easy control and versatility, to give high precision and good finish in a variety of gear forms. Apart from the straight-line feed, the machine has rotary motions only, which are uniform and continuous. Helical gears are also generated by rotation, without master gears, cams, or other special equipment. The differential mechanism permits any desired angle to be set up.

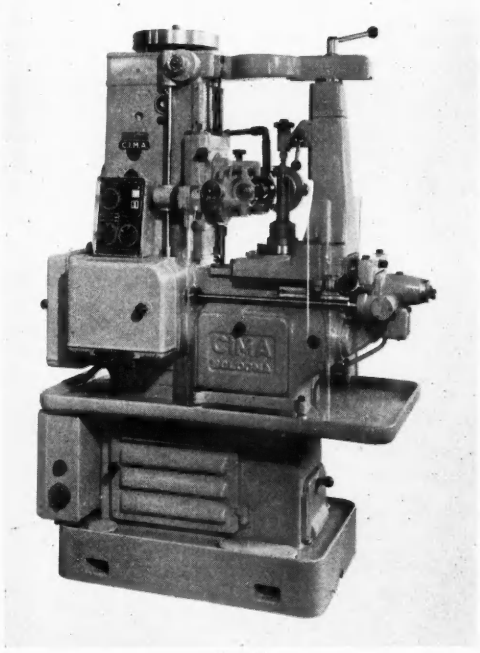


Fig. 12

As compared with earlier types, these gear generators have been designed with a view to generating gears by the uni-directional process, which reduces working time and provides a better gear-flank finish. Automatic traverse stops are provided for both working feed and rapid return, limiting error to a maximum of 0·015 mm, but providing for a dwell period when the horizontal carriage has stopped, so that the work can be given a perfect finish. A safety system is incorporated as a protection against operating errors and overloads, and is based on the special arrangement of the mechanical and electrical controls.

The milling machine, model FP6, exhibited by **Ing. Di Palo,** of Turin, derives its rigidity from the design of the frame, the knee unit, and the arm. Speed-gear changes are automatic and are controlled hydraulically, with the machine at rest, by duplicated levers, one in front and one at the side of the machine. A slight movement of these levers starts the rotation of a speed-indicating dial, which can rotate in either direction, thus facilitating the setting of the desired speed—an outstanding feature.

The feed rate can be read from two Vernier scales,

Fig. 13

one at the front and one at the side of the table, these being controlled by two levers. A notable feature is the solution of the problem of small, controlled vertical table movements, considering the weight of the knee assembly, fixtures, and work. The solution adopted in the FP6 is of simple design, but is highly effective, consisting of an oleo-dynamic system acting on the vertical screw, which thus operates as a hydraulic jack, relieving the considerable pressure between screw and locknut. As a result, operation becomes easy, and fractional movements can be effected by means of a small handwheel. This solution presents the further advantage that the wear of the screw and locknut is reduced to practically nil.

The above type of milling machine is the forerunner of the twin-spindle type (Fig. 13), which carries a robustly constructed vertical head on the arm. The principal characteristic of this head is that it permits vertical motion, and can at the same time swivel about a horizontal axis. It should be noted that all the motions of the vertical head, i.e., spindle speeds and feed, are derived directly from those of the horizontal spindle.

Giustina, of Turin, are exhibiting a number of their grinding machines, including universal grinders, rotating-table surface grinders with one and two heads, and centreless grinders.

Their rotating-table surface grinder (Fig. 14) works on a conventional system with an annular or segmental wheel mounted on the vertical spindle of the wheelhead, which also carries the appropriate motor. The circular table is magnetic. Grinding is carried out by the progressive vertical feed of the wheelhead linked with the rotation of the table. The table has steplessly variable speeds, which can be adapted both to the dimensions and the material of the work.

From the above, Giustina have evolved their new automatic surface grinder, which has an annular table and two wheels with vertical spindles, and which is being shown for the first time at this Exhibition. This machine grinds one face of the work in one pass under the two wheels, which carry out roughing and finishing respectively. The dimensions of the work are automatically kept within tolerances by means of two automatic caliper gauges mounted below the two wheels. The machine can be supplied with or without a magnetic table.

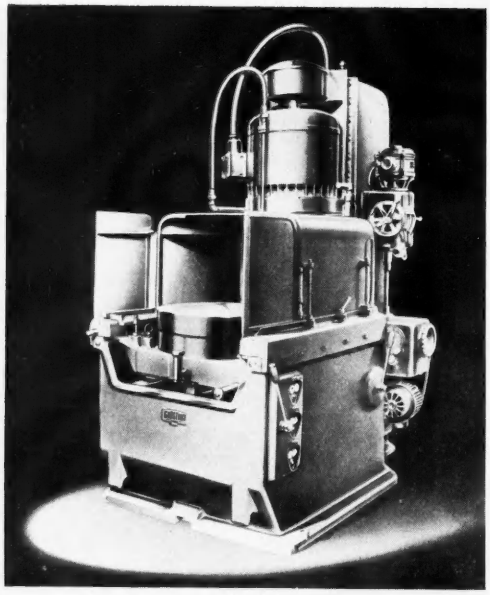


Fig. 14

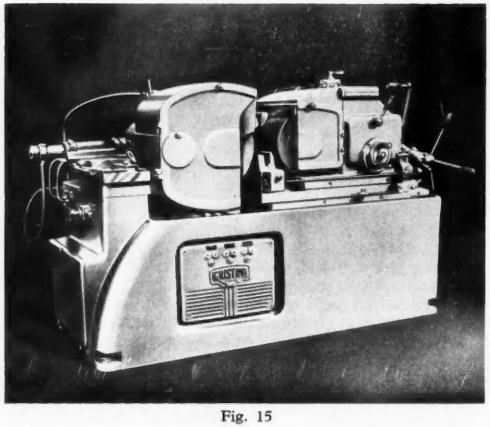


Fig. 15

Giustina are also showing their centreless grinder R150 (Fig. 15), whose control-wheel spindle is mounted on an efficient system of bearings and has an axial hydraulic-mechanical oscillating device which can easily be engaged by the operation of a knob ; this also controls oscillation amplitude, which varies from 0 to 6 mm. A better surface finish can thus be obtained for infeed work. Appropriate angular adjustment for obtaining a perfectly cylindrical form in work ground by the infeed process is provided, while, in the case of through-feed work, perfect contact between the work and the entire generating line of the control-wheel is ensured.

The firm of **Innocenti,** of Milan, is exhibiting a milling and boring machine, model CWB, which is of very large dimensions and is widely known in heavy industry in Italy and abroad. This machine (Fig. 16) is based on an appreciation of the importance of horizontal headstock feed on the slide for all milling and boring operations requiring the full power of the machine. This special arrangement renders possible high production by means of robust elements, and a heavy cutter spindle. Depth regulation is effected by axial headstock motion.

The problem of moving the headstock, which weighs from two to eight tons, with traverses of from 400 to 1000 mm, without excessive alteration of load distribution on the mobile supports, and hence without alteration of the thickness of the oil film and deformation the supports, has been solved by means of two patented devices which ensure even load distribution in all positions. The first of these devices clamps the headstock on the slide. The clamping point is close to the centre of gravity of the headstock. The longitudinal position of the clamping point can be varied by means of a regulating device when heavy equipment is mounted on the front face of the headstock and its centre of gravity is thereby displaced longitudinally. The result is that the load on the mobile support is reduced to a minimum value, which permits the most sensitive uniformity in the control of headstock feed, even at a low speed.

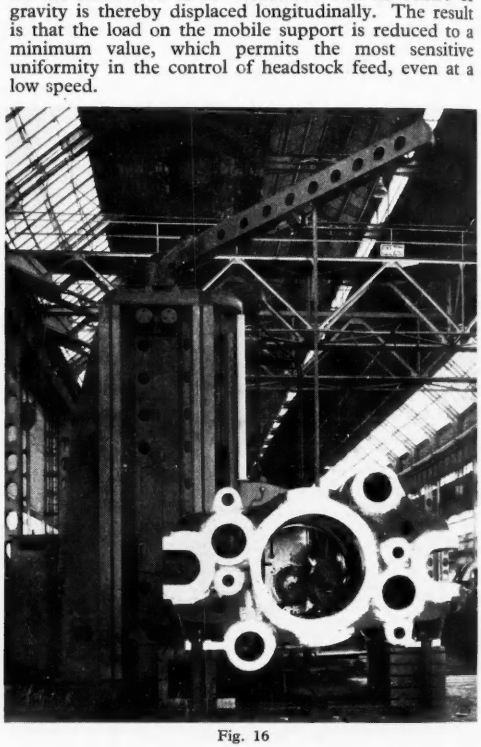


Fig. 16

A second device, operating concurrently with the first, prevents the horizontal motion of the headstock from causing load variations on the vertical way. For this purpose, a vertically moving variable weight is mounted on the slide, which maintains a constant, well distributed pressure, on the vertical way, preventing deformation of the way and diminution of the thickness of the oil film.

Other improvements relate to the balancing of the headstock assembly without the use of counter-weights, with their well known drawbacks, by means of a hydraulic device comprising a variable-delivery pump and a hydraulic jack of large dimensions ; the balancing effort can thus be regulated accurately.

The firm of **Mariani,** of Seregno, is exhibiting several machines for working sheet metal, including their new guillotine, model 145 CIN (Fig. 17), which has been evolved from their earlier guillotine, model 140 CIV. In this machine, blade angle is fixed, but is limited to very low values, so as to eliminate strip deformation ; for the same reason, the top blade

descends at a slight angle in relation to the bed. The frame of the machine is in heavy steel plate. Power from an electric motor, which is directly connected to the flywheel, is transmitted to a worm reduction gear, and thence to the main shaft of the machine, to drive the top blade and the hold-down plate. The latter exerts considerable pressure, so that the sheet metal is rigidly held; in order to provide continuous, dependable adjustment, where sheet-metal thickness varies from one point to another, the hold-down closing plate is fitted with a series of independent, spring-loaded fingers. Clearance between the blades can be set micrometrically, and the top blade can also be set with extreme accuracy. A rear stop with manual or electrical micrometric adjustment and registration on an indicator disposed frontally, serves for preset shearing widths, while shearing to a design is rendered possible by means of an apparatus which projects onto the sheet metal the exact outline.

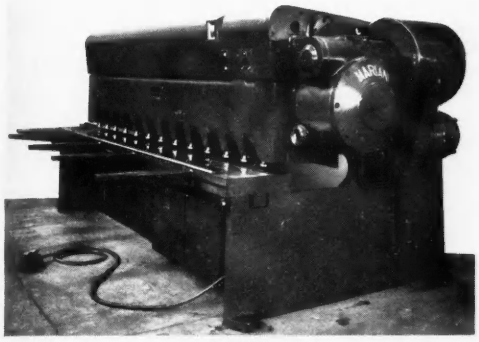


Fig. 17

Another new guillotine is model 149 CIB which has been designed to replace closed-frame guillotines, with which repetition shearing is not possible; this model is provided with gaps in the columns of 150 mm in depth. Drive is transmitted by V-belts from an electric motor to the control wheel and thence to the worm reduction gear. The hold-down closing plates exert very high pressures, and the rear guide is micrometrically adjustable.

The principal feature of the new multiple slitting shears, model 148 CCM, is its adaptability for different operating requirements. Its useful cutting width is variable, the shaft supports being axially movable. Special care has been devoted to massive construction, in order to ensure maximum cutting accuracy coupled with high productivity. The machine consists of an extremely robust frame which carries the cutter spindles, to which the drive is transmitted *via* a suitable reduction gear. It is equipped with a pair of guide rolls for the sheet metal, and with a pair of feed rolls whose pressure is pneumatically controlled.

Another new machine from Mariani is their press brake, model 147 PLA, with a pressure of 10 tons This machine is capable of bends of more than 1300 mm in length, i.e., the length of the bed, and repetition work is rendered possible by the gap provided in the columns. Speed reduction is obtained by means of a specially designed worm reduction gear. The ram can be arrested at any point of the cycle by means of a pedal-operated friction clutch, and its descent can be regulated according to the required bend.

Mariani's press brake, model 146 PLUS (Fig. 18), which has a useful length of 5050 mm, has been completely re-designed. The frame of this 250-ton machine is built in high-strength sheet steel and has been specially designed, bearing in mind the stresses arising from the very considerable working pressures and the high descending speed of the ram. The principal feature distinguishing this machine from other press brakes is its electro-pneumatic control system, provided to overcome the operating difficulty experienced with standard mechanical control of the friction gear engagement. This new type of control is simple to instal and operate and is easy to maintain.

The **Società Nebiolo,** of Turin, are exhibiting their vertical miller, model UFV (Fig. 19). In this generously dimensioned and robust machine, the spindle head slides

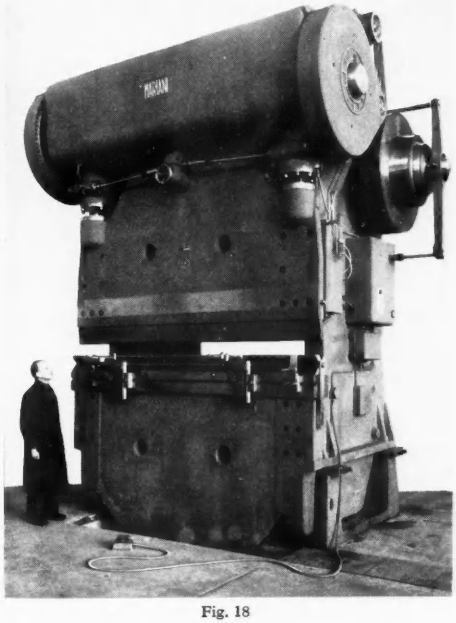


Fig. 18

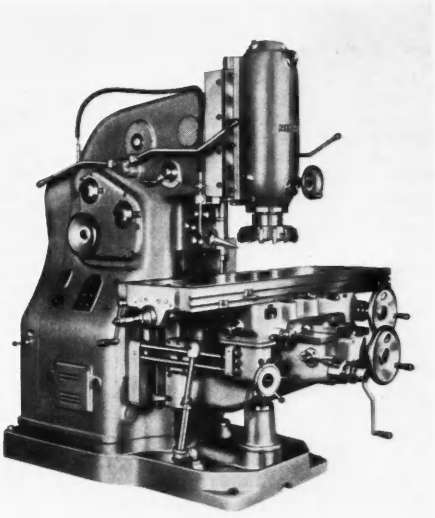


Fig. 19

vertically under manual control and keeps the spindle lodged in a series of preloaded conical roller bearings. The change-gear is designed to transmit to the spindle 12 speeds, which can be engaged by the operation of a direct-reading handwheel. The use of a pole-changing motor brings the number of available speeds up to 24. The knee assembly can be operated by hand, or automatically from the motor. The change-gear for the three automatic working feeds transmits 12 different speeds, which can be controlled by means of direct-reading handwheels. Here, too, 24 feeds are made available by means of the pole-changing motor. The new model embodies the following innovations, as compared with earlier designs :—Increased dimensions, with a wider and stronger base and column, and hence greater stability and absence of vibration ; extension of the vertical guides of the knee ; considerably increased useful table surface ; considerably increased spindle-speed range, with a maximum of 1400 rpm. Workmanship and finish are of a very high standard.

The firm of **Mannaioni,** of Florence, which has long specialised in screw-cutting lathes, is showing a new, high-speed machine, model MAN-4 V/700 (Fig. 20). This lathe has been specially designed for high-speed, precision cutting of threads of all lengths, types, and shapes, internal or external, right- or left-hand, tapered or cylindrical, single or multi-start. The high spindle speed, which ranges up to 2000 rpm, permits full exploitation of carbide-tipped tools.

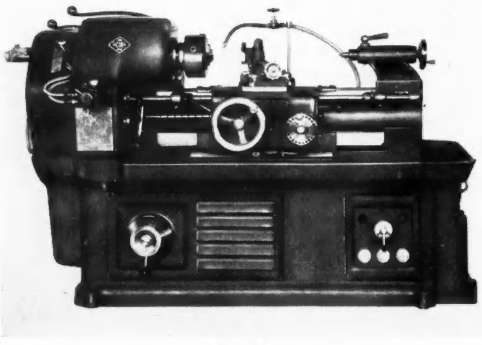


Fig. 20

Features of this original design include reversal of the lead screw and rapid return of the saddle, and provision for the gradual depth feed of the tool and its return to the starting point, and for stopping the tool at the end of the screwing operation in the correct position for the next piece. Setting-up of the machine takes only a few minutes, with a corresponding increase in output. The machine is equipped with interchangeable lead screws with which any standard thread can be cut. These lead screws can be changed with the greatest of ease and within a very short time.

With this type of machine, screws from a few millimetres to 50 centimetres in length can be cut, and the radial depth of thread may be as much as 3 mm.

The **Officine Meccaniche Olivetti,** of Ivrea, are exhibiting two examples from their extensive production range. One of these is a grinder, type RCO 800 (Fig. 21), with two laterally disposed heads, the spindle of one of which is parallel with the axis of the centres, while that of the other is at an angle of from 10 to 30 deg. These heads are standard Olivetti grinding units, i.e., grinding-wheel heads embodying a hydraulic control, by which automatic plunge-grinding can be carried out. The heads may have one or more grinding wheels and

Fig. 21

may be mounted on various types of beds and in various combinations of position, direction, and numbers. The principal features of these heads are :—Accessibility of controls ; a coolant and hydraulic system specially designed to eliminate vibrations transmitted from the pump ; automatic compensation of thermal expansion of the wheel head ; the possibility of single-lever control, automatic lubrication of guides, supports, shafts, and gears ; equipment for automatic plunge-grinding. This machine also possesses a wide range of hand-operated or automatic dressing tools mounted on the table or on the wheel head.

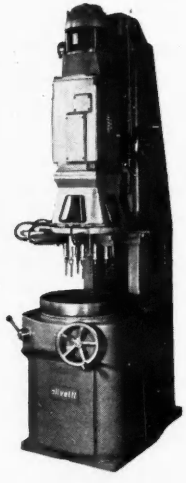


Fig. 22

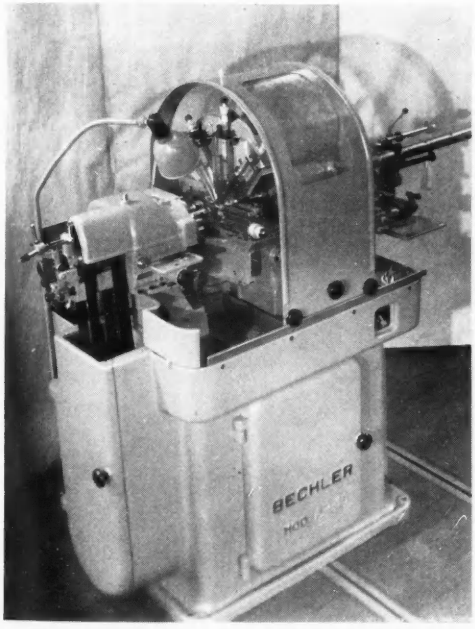
The second Olivetti machine is a multi-spindle drilling machine TMVO (Fig. 22), designed to meet requirements of productivity and adaptability. The table can normally be revolved by hand to two or four positions, so that the work can be clamped while the machine is in operation. The machine has eight adjustable spindles and one fixed spindle, with a wide range of speeds up to 1800 rpm. It can also be supplied with a fixed table and with mass-production attachments. Great care has been devoted to this type of machine, not only as regards design, but also as regards its constructional features and ease of operation.

Fourth European Machine Tool Exhibition, Milan

In our August issue, we previewed a number of interesting exhibits at the Fourth European Machine Tool Exhibition, which is being held in Milan between September 14 and 23, 1954. A further selection will be found in the following pages, These do not, however, include details of Italian machine tools, which are reviewed elsewhere in this issue.

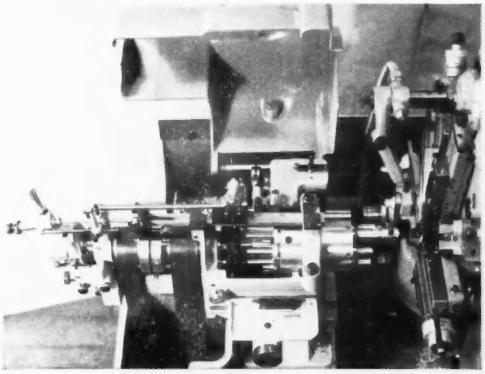
A new development by **André Bechler S.A.,** of Moutier, Switzerland, is a turret automatic with a sliding headstock, illustrated. The sliding headstock and cross tools are normal in this type of machine, but the six-tool axial drum turret, shown in close-up, represents a new departure.

The turret has six bores fitted with interchangeable precision bearing bushes; a range of spindles can be inserted in these bearings, and include stationary spindles for centering, drilling, reaming, or chamfering, revolving spindles for drilling or reaming, and threading spindles for right- and left-hand threads. The threading spindles run at different speeds and are driven by interchangeable precision gears; this method permits the use of up to six revolving or four threading spindles in the same set-up.



The turret tooling is very flexible and can also be adapted for drilling complicated stepped-diameter bores. Special adaptor spindles enable the use of various tool holders, which are rapidly interchangeable without having to remove the spindle. Turret indexing is hydraulic and is actuated by adjustable trip dogs mounted on the drum of the camshaft. Indexing time is independent of the camshaft speed and, in fact, occupies only a fraction of a second. Indexing is, however, smooth and almost noiseless. Accuracies unusual for any turret system are achieved by special bearings for the tool spindles, and by locking the turret on an indexing plate with a diameter larger than that of the circle on which the spindles are mounted. Adjustable safety stops are provided to protect the machine in case of accidents.

The size AR-10 machine exhibited is the smallest in the range and has a capacity up to 10 mm in diameter and 70 mm in turning length. It is equipped with a six-tool drum turret, as described above, five radial tool slides, headstock feed, and silent bar-stock feed. There is also a range of extra equipment which includes a screw head-slotting attachment, cross-drilling attachment, taper-turning attachment, and a rapid-motion drive to the camshaft for reducing idling time.

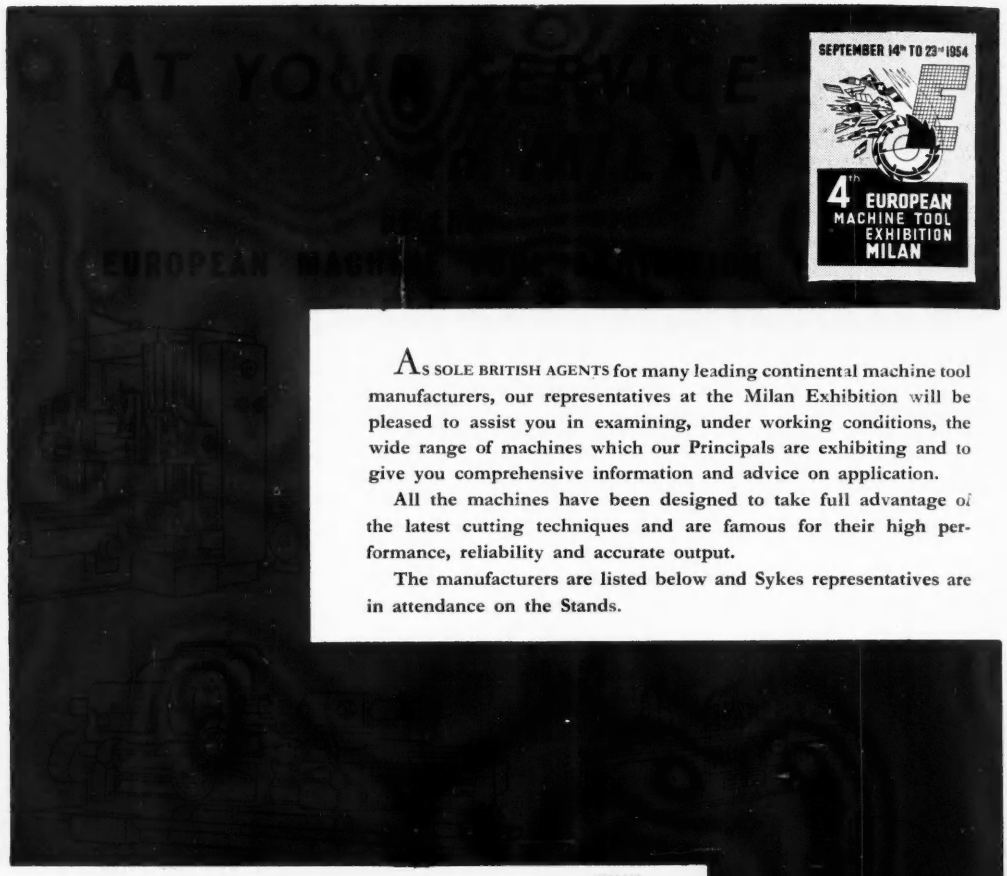


Greater accuracy, reduction of unproductive times, and increased scope are claimed as distinguishing features of this machine, in comparison with conventional Swiss-type automatics.

The **Swiss Industrial Company,** of Neuhausen Rhine Falls, are showing their SIG Copying Turret Lathe, type KD-35. By incorporating the copying principle in a light turret lathe, they claim to have developed an economically ideal machine for producing relatively complicated components in small or medium batches. In other words, the machine bridges the gap between an automatic and a centre lathe.

The machine has two slides, working independently. The main slide lies behind the spindle and carries an easily interchangeable disc-type turret-head with six tool positions. It also carries the longitudinal and transverse stops, and is intended for external tools, such as turning tools, knurlers, etc. The capstan slide is in line with the spindle and has a star-type capstan-head with six positions for drills, reamers, boring tools, etc. Indexing is either manual or automatic. The copying device uses a full-size sheet-steel template which is attached to the tool support. The copying finger is mounted on the disc turret head and transmits the template shape to the work. The spindle drive is steplessly variable between 60 and 3000 rpm, and the pole-changing motor has a capacity of 2·4 or 3·4 hp at speeds of 1400 or 2800 rpm respectively.

The height of centres above the bed is $5\frac{3}{8}$ in.; maximum bar diameter, when using collets and a three-jaw chuck, is $1\frac{3}{8}$ in. and $1\frac{7}{16}$ in. respectively. The maximum working length, using collets, is $7\frac{1}{16}$ in.; using a three-jaw chuck, it is $4\frac{1}{8}$ in., and for work between centres it is $5\frac{7}{8}$ in. The capstan stroke is $5\frac{1}{8}$ in. An unusual feature is the hip lever control for the longitudinal movement of the main slide. This frees the operator's hands for controlling the transverse and capstan slides and for switches, speed control, and clamping.



As SOLE BRITISH AGENTS for many leading continental machine tool manufacturers, our representatives at the Milan Exhibition will be pleased to assist you in examining, under working conditions, the wide range of machines which our Principals are exhibiting and to give you comprehensive information and advice on application.

All the machines have been designed to take full advantage of the latest cutting techniques and are famous for their high performance, reliability and accurate output.

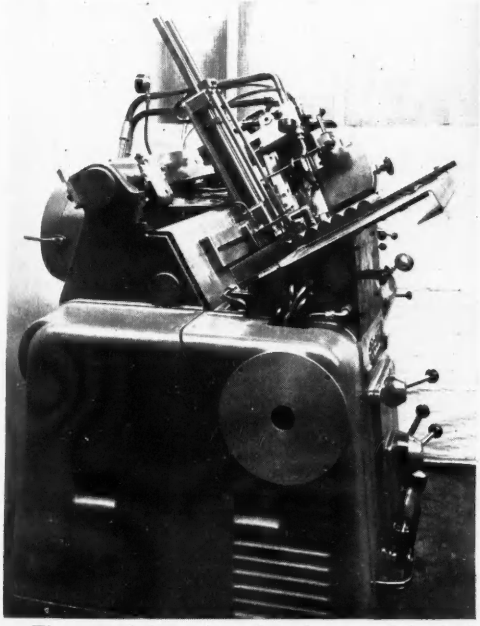
The manufacturers are listed below and Sykes representatives are in attendance on the Stands.

	STAND No.	HALL
THE V.D.F. LATHE GROUP including:		
GEBR. BOEHRINGER G.m.b.H.	7304	7
HEIDENREICH & HARBECK	to	"
H. WOHLENBERG K.G.	7307	"
BEKOMA BOEHRINGER K.G.	7306 / 7409	7
E. CORNAC	8201	8
ATELIERS PRECIS	8207	8
W. FERD KLINGELNBERG SOEHNE	7615	7
MASCHINENFABRIK RAVENSBURG A.G.	4907 / 4808	4
SCHAUDT MASCHINENBAU G.m.b.H.	7410	7
	9410	9
HERBERT BIERNATZKI	8225	8
FROEMAG		

SYKES

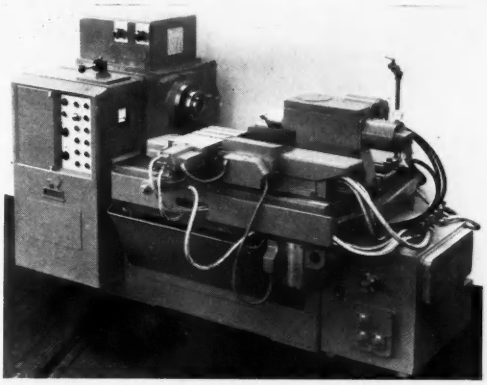
A highly developed and recently improved copying lathe is being exhibited by **George Fischer Limited,** of Schaffhausen, Switzerland. This particular machine, Model KDM-7/50, has automatic loading and a multi-cut recycling device, and is thus completely automatic. All the operator is required to do is to fill the magazine with blanks and to remove the finish-turned components. He can therefore look after a number of machines.

The magazine is placed above the headstock of the machine and the first blank is clamped between centres by hand. The spindle and the multi-cut recycling device are then started. After completion of turning, the work driver loosens itself and the tailstock withdraws automatically ; a lifting device then picks up the component and deposits it into a box. Simultaneously, a gripper, mounted on the feed carriage, picks up a new blank ; at that moment, the feed carriage is at the end of the run next to the headstock. As the feed carriage returns, the blank is pulled sideways out of the magazine and placed in the space between the centres. The loading device then pushes the blank between the centres, disengages itself, and returns to the starting point. Simultaneously, the tailstock approaches, the work driver clamps the work, and the working cycle of the multi-cut recycling device is engaged. The spindle stops automatically at the end of a run, i.e., as soon as the magazine is empty.



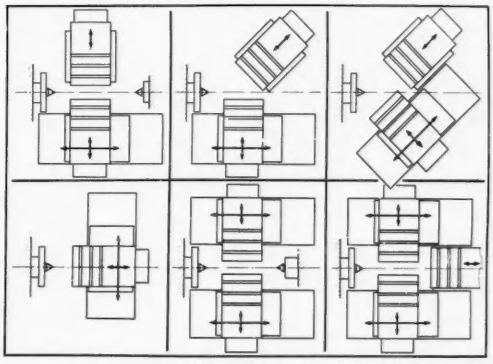
The control drum, located at the rear of the feed carriage, uses hydraulic valves, and controls the preset individual cuts by means of trip dogs fixed to the drum. The number of cuts, their depth, and length can be selected to suit the component. The machine also has an automatically swivelling template holder, so that roughing cuts can be taken off one template and finishing cuts off the other, without reclamping the work. The setting up of the machine for several cuts, i.e., the adjustment of the control drums, is a fairly lengthy job. For work which is likely to recur, it is advisable to adjust one drum, remove it from the machine at the end of the run, and store it until needed again.

An unusual new production lathe, Model DP 604, is being exhibited by **Ludwig Loewe and Co.,** of Berlin, Germany. The machine is electro-hydraulically



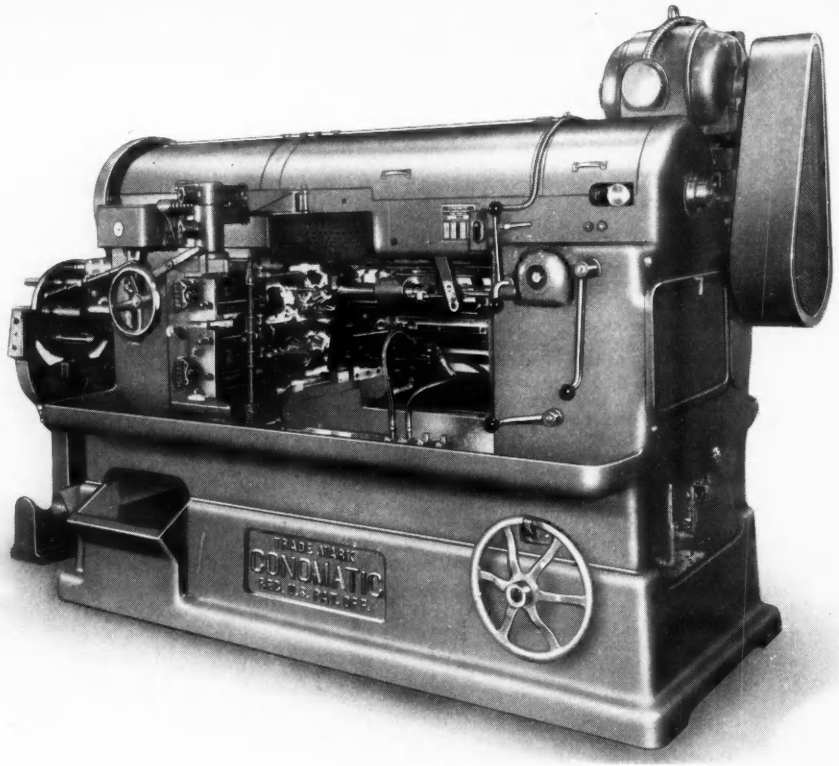
controlled and is fitted with a 20-hp main drive motor ; it can therefore be used for heavy metal removal. The compound front rest can be used as a copying slide rest or as a multiple tool rest, without the need for resetting the machine. For copying, a tracer, working off a flat template, is fitted. Adjustable stop dogs are also available for normal multi-tool cutting without a template ; a combination of template and stop-dog control can also be employed. There is also an independently operated undercutting slide rest and air-operated tailstock.

The most interesting feature of the machine is the number of ways in which tool rests can be mounted on the bed, which is itself designed to serve as a work-table. Self-contained unit rests can also be used in place of the normal rests. These various arrangements, shown schematically below, considerably increase the scope and versatility of the machine.



The sequence of operations is controlled semi-automatically by a lever. This lever is movable in two planes and controls firstly the clamping mechanism, then the spindle rotation and, finally, the start of the operational cycle of the tool rests. At the end of the cycle, the rests return to their starting position and the spindle stops automatically. This versatile and basically simple machine is relatively easy to operate.

A recently improved copying lathe is being exhibited by **Eduard Dubied & Co.,** of Neuchatel, Switzerland. Known as the 515 Rapid Copying Lathe, it has constant cutting speed and constant feed per revolution. Constant cutting speed, irrespective of the diameter being machined, is obtained through a steplessly variable drive, and this is controlled electrically, according to the position and movement of the tool slide. Constant feed rate is achieved by mechanical connection of the hydraulic feed system with the main spindle. This



MILAN **FOURTH EUROPEAN MACHINE TOOL EXHIBITION**
14th–23rd SEPTEMBER, 1954

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(GREAT BRITAIN) LIMITED

extend a cordial invitation to visit

STAND 7110 HALL 7

where the $1\frac{5}{8}$" 6-spindle

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Initial Manufacturing Programme includes
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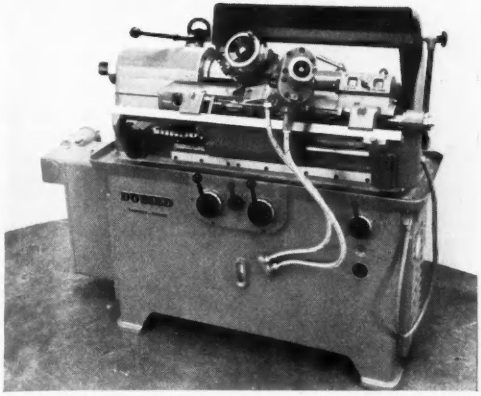
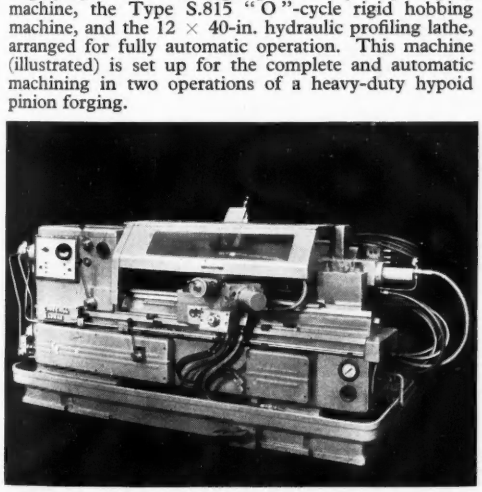
constant feed per revolution of the work ensures perfectly uniform finish over the whole workpiece. Both these features are also said to improve machining efficiency and tool life.



The latest model also has the steplessly variable hydraulic feed of the older Dubied machines. The heavily ribbed bed is connected to the pedestal at three points, and the bed is steeply inclined for better cutting-load distribution and for easier chip disposal. A large fixed guard is placed round the back of the machine, while a sliding guard, covering the headstock and the tool slide, protects the operator at the front. The hydraulic copying system is balanced and very accurate, and corners with 90-deg. sides on rising cuts and 30 deg. on plunging cuts can be machined. The template-to-work ratio is 1:1, so that sample parts can be used as patterns. The machine can accommodate up to 25⅝ in. between centres, and the maximum turning diameter is 3¼ in. Spindle-speed ranges of 300 to 2100 rpm, or 570 to 4000 rpm, are available, the main drive motor being 7 hp.

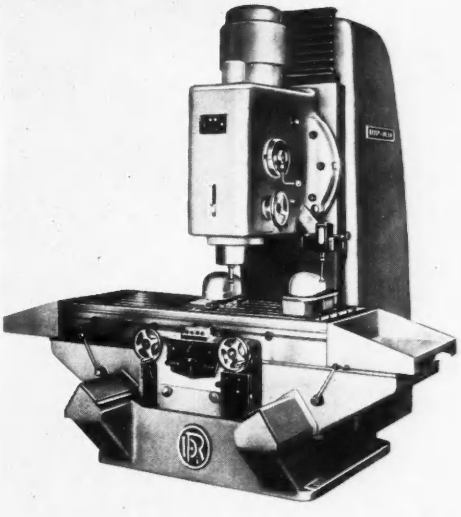
Churchill-Redman Ltd., of Halifax, England, are displaying their 24-in. high-speed heavy-duty shaping machine, the Type S.815 "O"-cycle rigid hobbing machine, and the 12 × 40-in. hydraulic profiling lathe, arranged for fully automatic operation. This machine (illustrated) is set up for the complete and automatic machining in two operations of a heavy-duty hypoid pinion forging.



The machine possesses a number of outstanding features, including automatic spindle-speed change. It is possible to change spindle speed by means of carriage trips and, since the machine is also provided with automatic multi-cut control, this can be done during any one of four cycles. Feed change is also automatic and enables one of two feed rates to be selected automatically on any cycle, at any position of the carriage. Two feed rates are available, but these can be pre-selected anywhere within the feed range of zero to 17 in. per minute. The automatic multi-cut control, mentioned above, is designed to make possible the turning of components on a fully automatic cycle, when stock removal is larger than can be dealt with in one pass. Up to four successive cuts can be taken automatically, and the tool is positioned automatically for the depth of cut required for any pass. The last pass is normally made under complete control of the template.

The machine also has an automatically controlled, hydraulic rear slide, which can carry tools for facing, grooving, or undercutting. It has rapid power traverse for approach and return, and the infeed is steplessly variable. It is claimed that diameters and lengths can be reproduced from the template with an accuracy of 0·002 in., while the template slide is arranged for micrometer adjustment in two directions. This particular machine will swing 6 in. and 16 in. over the top slide and the saddle respectively and admits 40 in. between centres. It has 36 headstock spindle speeds, from 130 to 1760 rpm, and a two-speed main drive motor of 15 hp. The machine occupies a floor space of 11 × 5 ft. and weighs 11,200 lb.

A recently improved and fully developed vertical copy-milling machine, Type FS 120 sku, is exhibited by **Droop & Rein,** of Bielefeld, Germany. The machine, which is of pleasing appearance, has a copying unit actuated by a tracer finger which transmits the contours of the template or master to a circuit containing a number of electromagnetic clutches. These, in turn, control the milling-head movements. No electronic or hydraulic equipment is used.



Fully automatic contour milling in two planes can be achieved by using a special feeler; in this way, external or internal contours can be machined round 360 deg., without the operator having to control the direction of movement. Fully automatic area-milling in three planes is also within the scope of this machine, a reciprocating, progressive feed movement being used. This latter operation is shown on the above illustration

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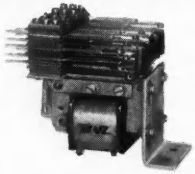
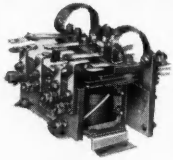
the type J.0.1. MINIATURE LAMINATED-FRAME RELAY

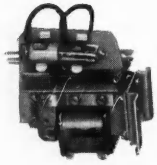
Small — but has power to spare, allowing heavy contact pressures with low coil dissipation.
Very quick, dead-beat, buzz-free operation on A.C. or D.C.
Fitted with buffered contacts, stainless steel armature shaft and "Oilite" bearings.
Like all B & R relays the J.O1 is fully tropical and is insulation tested at 2,000v.



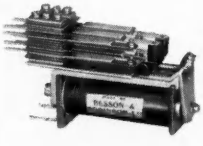
TYPE C.01
The large brother of the J.01. Even more sensitive and with higher contact ratings.



TYPE C.03
A contactor with make, break or c/o contacts. Special types fitted for D.C. and very inductive loads.



TYPE C.05
Mercury switch relay for up to 2 pole 30 amps. An alternative model can be up to 3 pole 60 amps.



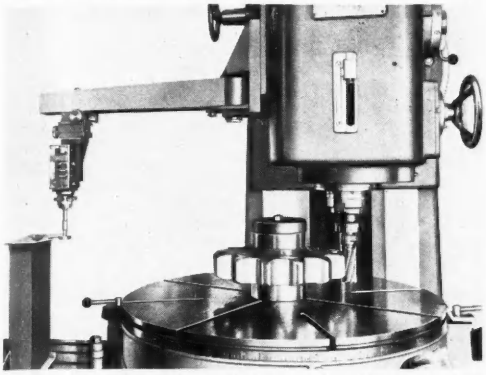
TYPE B.01
Takes as little as 0.05 watt D.C. yet has contacts *designed* for mains voltages.

BESSON and ROBINSON RELAYS
Sole Distributors,
OLIVER PELL CONTROL LTD.
Woolwich 1422

TO OLIVER PELL CONTROL LTD.
Cambridge Row, Woolwich, S.E.18
Please send me further details of B & R relays ☐
Please arrange technical representative to contact me ☐
NAME .....
COMPANY .....
ADDRESS .....

of the machine, whereas contour milling in two planes is shown below.

The machine can also be used for normal vertical milling and for this purpose the longitudinal, cross, and vertical movements can be under power or by hand. The spindle head carries a 20-hp motor and can be moved along the column by hand or mechanically.



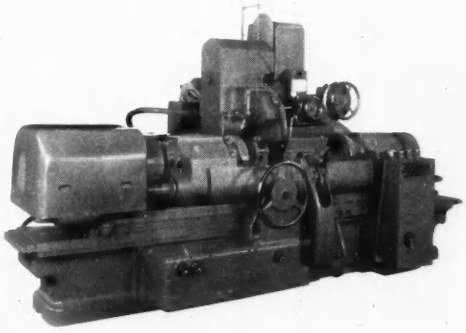
The spindle itself is carried in adjustable preloaded bearings mounted in a long sleeve and can be adjusted by hand for fine vertical setting. The column is rigidly constructed and contains the headstock counterweight. The table rests on the bed on two inverted V-shaped ways, which are widely spaced to minimise tilting of the table. All guide ways and slides on the bed and column are effectively covered in any position of the table or headstock. The maximum vertical movement of the head is 5·9 in. and its highest and lowest positions over the table are 31·4 in. and 2 in. respectively. The table is 70 in. long and 31·4 in. wide; the longitudinal movement is 58 in. and cross movement 27·5 in. There are eighteen spindle speeds, between 20 and 1000 rpm, and both the headstock and table feeds are steplessly variable. Rapid traverse is provided for the headstock and table.

The latest version of their large crank-pin grinder is being exhibited by the **Landis Tool Company,** of Waynesboro, Penn., U.S.A. The machine illustrated, known as Type DH, will swing 16 in. and will accommodate lengths up to 42 in., although models are also available to swing up to 25 in., with maximum lengths of 32 in. and 72 in.; 4-, 6-, or 8-cylinder crankshafts can be dealt with, and the machine is used in the automobile aircraft, tractor, and other industries, wherever precision grinding of crank-pins is required. A hydraulically operated overhead wheel dresser is provided and this enables wheel dressing to be carried out without changing the work set-up.

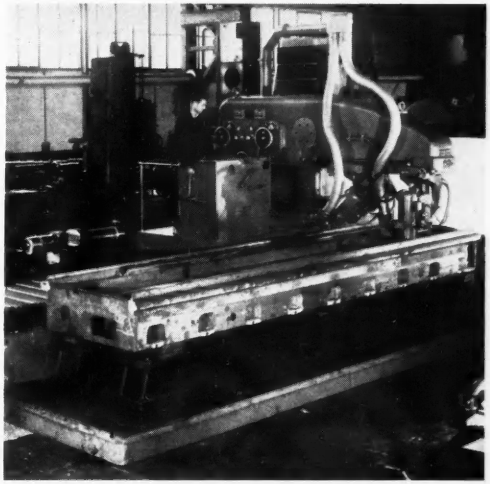
A useful additional feature is the compensating wheel feed, which resets the wheelhead to correct the position after dressing. The carriage and wheelhead ways are lubricated from a separate reservoir by means of a pump and filter. Telescopic covers protect the ways, regardless of the position of the carriage. A sensitive hand feed for the carriage is a new addition and this enables the crankshaft to be positioned laterally as the grinding wheel moves towards the work, so that each side of the crankshaft sidewall can be ground evenly. Controls for adjusting the hydraulic traverse speed are at the front of the machine, and there are separate controls for the positioning speed of the carriage and for the right-hand and left-hand cushioning speeds.

The special spindle bearings are pressure lubricated, while a safety pressure switch is incorporated, to prevent rotation of the spindle unless there is adequate pressure in the bearings. A similar switch is incorporated into the guideway lubrication system. A steplessly variable-speed motor is provided to maintain the correct wheel surface speed, regardless of wheel diameter.

The machine exhibited removes 0·030 to 0·040 in. from four crank pins and adjacent radii. It also removes 0·010 in. from the sidewalls. The production rate is 80 complete crankshafts in 8 hours at 100% efficiency. Automatic sizing equipment is available, if required.



The grinding of long machine-tool slideways is becoming well established and a number of slideway grinders is available. A new, highly developed machine for this purpose is being exhibited by **Vereinigte Österreichische Eisen- und Stahlwerke,** of Linz, Austria. Its most interesting feature is the particular template operation which ensures accurate and consistent matching of the slide and its counterpart.



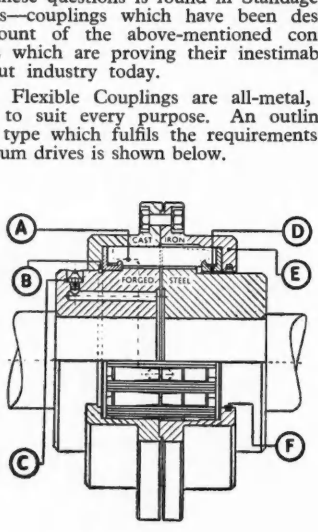
Two grinding heads, mounted on an outrigger, travel along the workpiece, which is held stationary. The whole machine is mounted on a baseplate; the bed, which is mounted on this baseplate, has accurate V- and flat guides, and carries power-supply rails from which contact fingers on the cross table pick up the current. The table, which moves along the bedways, is long and rigid and houses a hydraulic reservoir and hydraulic movement gear. Leather bellows are provided to protect the bedways. The table also carries the panel for the control of table speed and spindle speed of the grinding heads. Table-travel limit stops are also mounted on this panel. A useful safety device

Couplings Solve Engineers' Problems

All-Metal, flexible types for power-transmission without fear of breakdown

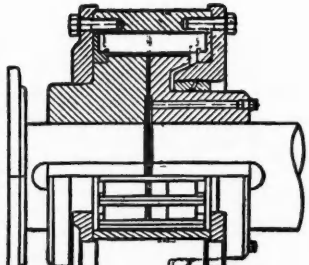
When power has to be transmitted from a prime-mover, through a shaft, to a driven machine, a number of factors have to be considered: axial mal-alignment, obliquity, torque, shock and vibration. What is the best method of overcoming all these? How can one be sure that the transit will be satisfactory? The answer to both these questions is found in Standage Flexible Couplings—couplings which have been designed to take account of the above-mentioned conditions—couplings which are proving their inestimable worth throughout industry today.

Standage Flexible Couplings are all-metal, and are supplied to suit every purpose. An outline of the standard type which fulfils the requirements of light and medium drives is shown below.



(A) Laminated Spring Silicon Steel Driving Members
(B) Spring Steel Locking Ring
(C) Oil Valves
(D) Retaining Springs
(E) Solid Flanged Cover
(F) Felt Oil Retaining Ring

It is designed to be very resilient under light torques, the resilience decreasing until it becomes sensibly constant at a pre-determined value within the range of working torques. In the event of heavy overload torques, the resilience decreases still further until, at a certain point, the coupling becomes, virtually, a solid transmitter of the drive. This condition does not come about suddenly, since the oil film between each Spring Lamination provides a cushion which could only be broken down under extreme pressure.



Another coupling is the self-supporting type. This is a modification of the standard coupling, and in order to obviate one of the adjacent bearings, a centralising device is incorporated. This comprises a spherical seating and bearing on the driven half, and serves the dual purposes of supporting the shaft and also making a perfect oil seal. Being non-rotating, wear is negligible, giving a length of service equal to that of the coupling. Another point is that this coupling eliminates the installation of a plummer block.

Space does not permit further illustrations, but information on the right coupling for your purpose will be gladly submitted. Owing to greatly expanded business, and in order to cope with increased demand, a new factory has been acquired at Newhaven, Sussex, which will soon be in full production. In the meantime, enquiries should be sent to the London works.

4th EUROPEAN MACHINE TOOL EXHIBITION MILAN

Literature describing the range of **Standage Power Couplings** can be obtained at **"The Engineers' Digest," Stand No. 5035.** where a representative will be pleased to deal with any enquiries from visitors relating to this Company's products.

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consists of pilot lamps, indicating the operating direction of the table and grinding heads. These lamps are mounted on the control panel and outrigger, and operate even when the machine is at rest. A hollow column is secured to the table, and its guides carry a saddle, on which is mounted the swivelling outrigger, which can be adjusted vertically, swivelled, and set to any desired angle. The grinding heads are mounted on the lower slide of the outrigger. The cross and longitudinal movements of the heads on the outrigger can be operated by hand from the operator's station or from the front of the outrigger. The heads themselves can swivel about their horizontal axes, giving almost universal adjustment. A wheel-dressing device is attached to the heads and is raised hydraulically to the required position for dressing. The dressing operation is by hydraulic remote control.

A grinding template is fitted to an extension of the head guides. The template determines the final dimensions and shape of the ground ways. A tracer finger, mounted on the dressing device, makes contact with the template and automatically disengages the feed mechanism, as soon as the preset dimensions are reached. Until the preset dimension is reached, a green pilot light shows on the outrigger for each grinding head. As soon as the feed mechanism is disengaged, a white lamp lights up independently for the two heads. When working to given tolerances, the feed movement can then be restarted by releasing a catch. When the tolerance has been exceeded, a red lamp is illuminated. The tolerance range, i.e., the period between the extinction of the green lamp and the illumination of the red lamp, is adjustable. An ample supply of coolant is provided for both grinding heads and, where dry grinding is preferred, a dust-removal plant can be installed. Maximum table travel ranges from 9 ft 10 in. to 39 ft 4 in., according to the type of machine, seven sizes of which are available. Maximum diameter of the cup-type grinding wheel is 11¾ in.

An unusual cutting-off machine is being exhibited by the German firm of **Gottlieb Gühring,** of Ebingen. It has vertical spindles to save factory floor space, while two spindles operate simultaneously for increased output. If necessary, two bars of different diameters can be dealt with at the same time. Drum-type magazine loading is used, and 36 or 40 bars can be loaded simultaneously; reloading can be carried out while the machine is in operation and, when the magazine is empty, the machine will stop automatically. Owing to the design of the loading mechanism, bars can be used up until only about 1/32 in. is left as waste. The ends of bars, bolts, pins, etc. can be cut off flat, rounded or pointed, or one end can be pointed and the other flat or rounded. The pieces cut off are carried through channels to a collecting bin, while swarf and coolant are collected separately.

All controls, with the exception of those for the tool carriages, are coupled and are operated by a simple clutch. A quick-acting clutch ensures instantaneous stopping of the tool carriages, and these can then be withdrawn by a handwheel. All working parts of the machine are easily accessible after removing two hinged guards. Automatic safety devices come into operation if the preset feed pressure is exceeded, or if oversized bars prevent the magazine from rotating. The cause of machine stoppage is indicated on one of a series of lamps on the centre panel. A counting disc is provided for indicating the number of pieces cut off a bar. A steplessly variable drive permits the selection of the optimum cutting speed.

The larger machine, Model 51, can deal with bars up to approximately 1 3/32 in. in diameter and 118 in. in length, the minimum and maximum lengths of components cut off being 1¾ and 10 in. respectively. It is claimed that up to 1800 components per hour can be produced, using both spindles. Owing to the automatic magazine loading and safety devices, one operator can look after several machines. Furthermore, the machine can be left running during breaks or after hours, when the machine will automatically deal with one magazine load and then stop.

Among the heavy metal-cutting machines exhibited by **Berthiez,** of Paris, is a new vertical boring and turning mill, type 9130, illustrated. This machine is of intermediate size for its class, and although it can be used for relatively small diameters, its maximum capacity is approximately 12 ft. 6 in. The table is 94 in. in diameter and it can accommodate a weight of 50 tons. The machine, which weighs just over 50 tons, has a very wide speed range, allowing a 12-in. diameter to be bored at 300 fpm, while the maximum diameter can be machined at a minimum speed of 16 fpm.

The table is mounted on flat, non-metallic ways and is centred on two precision roller bearings. The machine, which can be equipped for taper turning, screw cutting, and electronic copying, has a single upright and the

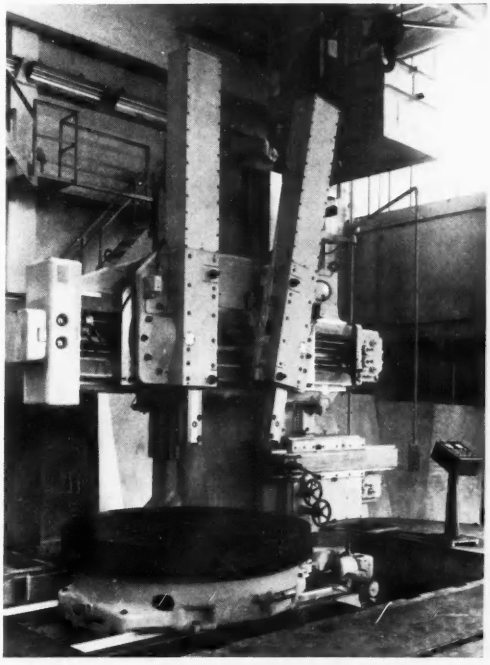

table is displaceable along the ways in a direction parallel to the tool carriage arm. This facilitates the accommodation of work of various diameters. Table speeds are steplessly variable. The arm is guided by two front slides and one side slide, and is reinforced by a massive buttress, resulting in great rigidity.

An independent motor is provided for the vertical movement of the arm, and the locking of the arm is effected hydraulically. The machine has two tool holders on the arm and one side tool holder, all of which have a heavy rectangular ram. The two tool holders on the arm are of the swivelling type. Push-button controls are located close to the tool holders, as well as on the central panel. The main controls can also be operated from the pendant control panel.

The **Micromatic Hone Corporation,** of Detroit, U.S.A., is showing a number of micro-honing machines, including Model 739, which, in the illustration overleaf, is tooled up for honing a bearing, and is equipped with

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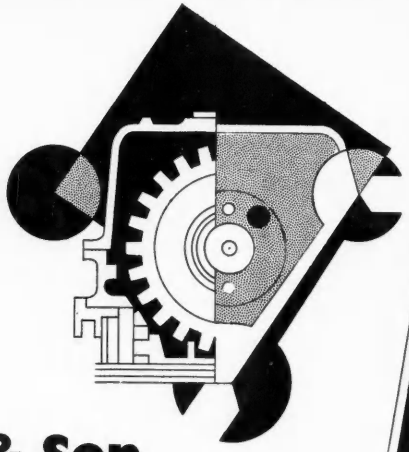

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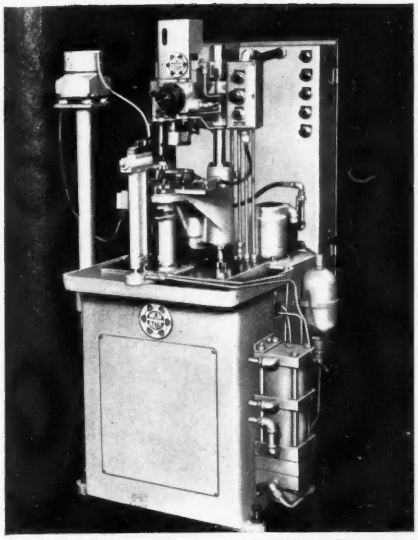
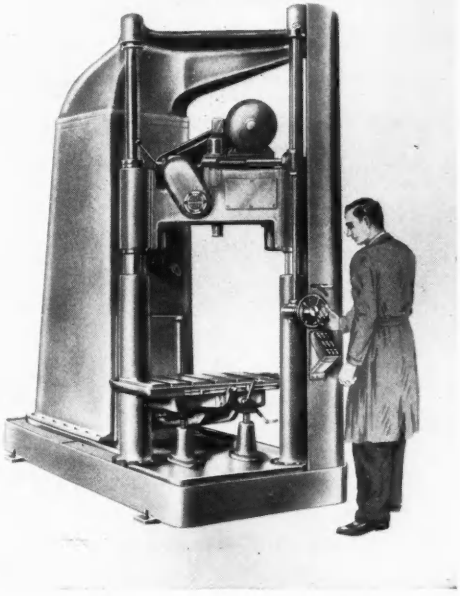


an automatic fixture and automatic sizing. The machine has a self-contained head unit, supported by two bars, and is automatically splash-lubricated. The spindle drive shaft reciprocates and rotates, both motions being powered by one motor. The length of stroke is easily adjustable by means of a graduated scale. The saddle carrying the fixture is supported on the same two bars, and is designed in such a way that parts which are longer than the machine stroke can be honed. This model is particularly suitable for small diameters. The spindle stroke is 1 in. and the maximum bore is $\frac{3}{4}$ in.

The advantages of the micro-honing process are well known and include efficient and controlled minute stock removal, the production of strictly geometrically accurate bores, the maintenance of size tolerances to within 0·0001 in., and the production of a consistent and uniformly good surface finish.

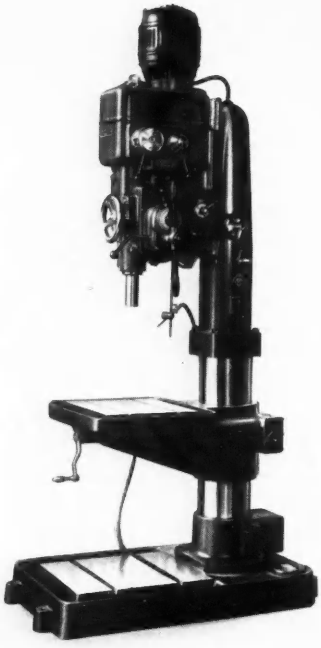
This company is also displaying the new general-purpose machine illustrated, for diameters ranging from $1\frac{1}{2}$ in. to 6 in. and lengths up to 26 in. The machine is easily adaptable for multi-spindle and automatic sizing operation. It is being shown publicly for the first time, and will be built in England under license.

An interesting special-purpose machine for grinding the tracks of ball-bearing races is exhibited by **Albert Tripet S.A.,** of Bienne, Switzerland. It is designed for the extreme accuracy required for the very close tolerances in this type of work. The grinding head has an oscillating movement, adjustable between 0 and 35 deg. each side of the central axis. This movement can be stopped instantaneously by means of a clutch operated by a hand lever. The point of the dressing diamond, whose holder is mounted on the central axis of oscillation, is used as the datum for controlling the grinding operation.



The machine is capable of grinding the inside of outer races and the outside of inner races. High-speed spindles, driven by compressed-air or high-frequency motors, are used for internal grinding work. The makers claim that, owing to the robustness and accuracy of the machine, it is possible to grind the track shape to within a fraction of 0·001 mm, and to produce extremely smooth, chatter-free surfaces. The wheel dressing and approach are controlled by hand, whereas the oscillating movement is automatic. One operator can serve two machines.

The capacity of the machine, which is known as Type MUS-CB 2.000, is as follows :—Maximum diameter of outer races, 52 mm ; maximum diameter of inner races, 30 mm ; maximum radius of ball tracks, 6 mm. The machine is suitable for both batch production and " one-off " work.



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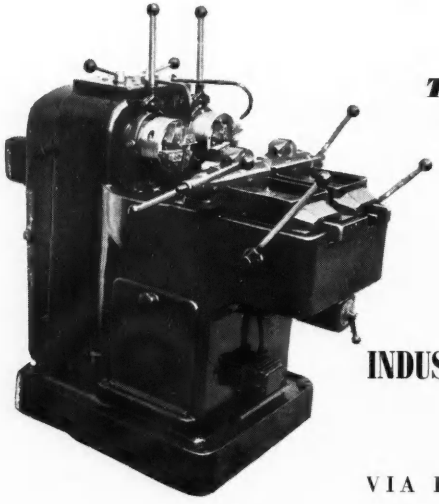

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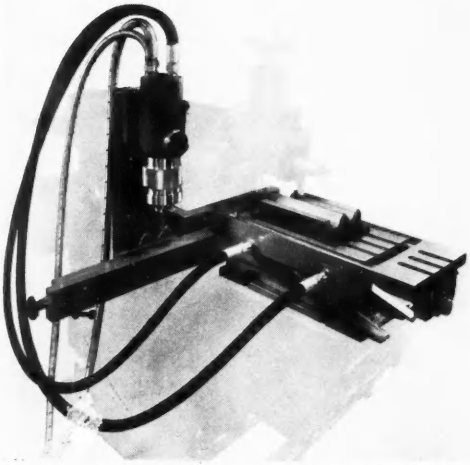
The Swiss firm of **Bondy S.A.,** of Fribourg, is exhibiting several types of their well known "Bondycop" copying attachment, including the one illustrated, which has been specially designed for use on shaping machines. It is claimed that the attachment can easily be mounted on most shaping machines, and that the time required for this operation is about two hours.

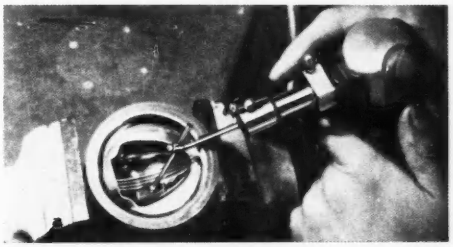


The attachment is hydraulic and consists of a hydraulic pump system driven by an electric motor, a feeler control system, and a table with a built-in hydraulic system, together with the necessary hydraulic piping. The working surface of the table is 240 × 560 mm, the size of the base plate, which is mounted on the shaping-machine table, is 210 × 470 mm, and the vertical movement of the hydraulic table is 51 mm. This movement also represents the maximum copying height.

It is claimed that the attachment is so simple that a shaping machine thus equipped can be operated by semi-skilled labour.

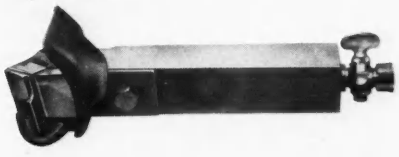
Among other small equipment which is being exhibited is a very useful range of reciprocating hand tools, manufactured and marketed by **Diamantprodukter AB,** of Hägersten, Sweden, under the name of "Diprofil."

These small power-operated tools impart a reciprocating motion to a spindle, on which can be mounted a wide range of special tools, including diamond needle files of rectangular, circular, and elliptical section, and special disc-shaped diamond files, joined to the tool *via* a ball joint. This joint imparts to the tool a circular motion, which is particularly useful for large flat or curved surfaces and ensures even and rapid metal removal. Scraping, normally a tedious hand operation, can be performed efficiently, using a tungsten-carbide scraper inserted into the reciprocating spindle.



One of the most useful applications of these tools is for honing, lapping, and polishing, using stone, sintered synthetic sapphire, or abrasive rubber hones, or cast iron, copper, fibre, wood, or felt laps. These hones or laps are mounted on special shoes and are attached to the tool spindle by special holders, which, though relatively simple, are ingeniously designed to reach relatively inaccessible points on dies, moulds, and other components requiring honing, lapping, or polishing. A typical example of the usefulness of these holders is illustrated above, and shows the polishing of an internal curved surface on a mould.

The firm of **Eduard Ifanger,** of Uster, Switzerland, is showing a range of cutting tools, including a number of heavy-duty lathe tools. Some of these are tungsten-carbide tipped and are made on the tangential-tool principle; they therefore require regrinding on the top surface only. Regrinding is thus simpler and quicker.



Of particular interest are those tools provided with internal cutting edge cooling, as illustrated. Coolant is supplied under pressure through the tool shank and the tool has a specially designed adjustable chip-breaker. Heavy machining is possible without producing undesirably long and unwieldy chips, as, owing to the design of the chip-breaker, the swarf consists of short lengths of tightly rolled coils. Exceptionally heavy cuts, with long tool life, are claimed as advantages of these tools.

A new, simple, automatic sizing device for machine tools, recently introduced under the name of "Sigmatic Machine Controller," is being exhibited by **Sigma Instrument Co. Ltd.,** of Letchworth, England. This device is designed to control the infeed motion of machines and to stop such motion when the component reaches the predetermined correct size. As the controller and therefore the machine are governed entirely by the gauge on the component, the final size of the component is independent of machine-tool inaccuracies or deflections, and of tool or wheel wear.

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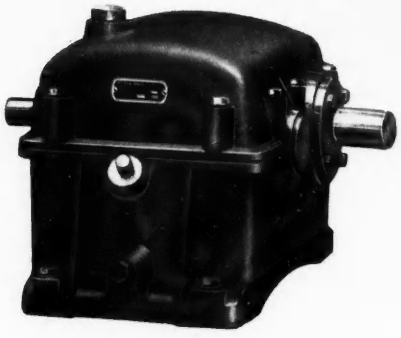

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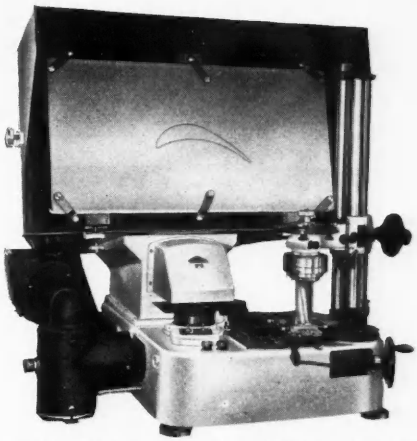
The gauge in contact with the work consists of a caliper, bell-crank lever, or expanding plug gauge, depending on the machining operation. Air at constant pressure is used as the measuring medium, but the operation of the whole unit is dependent on a combination of new pneumatic and electromagnetic systems. The gauge contains a calibrated valve, which converts a dimensional movement as low as 0·00001 in. into a measurable change in air pressure. A unit, sensitive to pressure changes, converts the pressure signal into an electrical impulse, which energises a self-locking relay. This relay can operate as a two-stage controller, when it will control the machine mechanism to re-dress the wheel and to reduce the infeed rate, in the case of a grinder. Additional metal removal causes a continued steady change in air pressure; when the preset size is reached, a second relay comes into operation and gives the signal for terminating the machining process.

The controller can be used on a magazine-loaded machine, when contact between the gauge and the pre-machined component restores the controller to the commencement of the cycle automatically. Manual re-starting is also available, and a safety interlocking system then ensures that the previous cycle can not be cancelled until the operator presses a button. The controller operates correctly on pressures of 50-100 psi., and incorporates an air-pressure regulator and air filter. Two control knobs are provided to regulate the pressures at which the two signals act in two-stage operation; they therefore set the pressures for terminating "roughing" and "finishing." The controller works equally well as a single-stage controller to stop the machine only when final size is reached, if the machine automatically changes from roughing to finishing feed. A simpler single-stage controller is also produced.

An interesting British instrument, the model E Projection Pantometer, manufactured by **Optical Measuring Tools Ltd.,** of Maidenhead, is being shown by Newall Group Sales Ltd., of Peterborough. It is intended for the inspection of three-dimensional contours, such as those of turbine blades, where normal shadow projection is not possible, owing to the interference of the light beam with the twist in the blade.

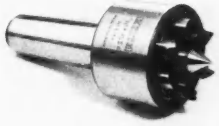
The part to be inspected is held vertically in a holder which has rotational movement and easy height adjustment. Two diametrically opposed styli are mounted



on a freely floating table and are lightly spring-loaded against the blade sides. The blade contour is followed by one stylus by rotating a single knob. As soon as this stylus traverses one side of the blade, the other stylus is automatically brought into action and traverses the other side of the blade. The floating table also carries a graticule consisting of two arcular spots containing the appropriate work tolerance and spaced equidistantly from the two styli. As the stylus follows the blade contour, the graticule follows an identical path. The graticule is projected onto a screen by means of an optical system. The screen also contains the master in the form of a tracing on translucent material drawn with a magnification of $\times 10$. The tolerance circles move around the drawn master contour and any departure from true form or position is readily observed. The screen measures 24 $\times$ 12 in., and the maximum length of component the instrument can accommodate is $16\frac{1}{4}$ in.

This particular model is specially suitable for work necessitating frequent design changes in the inspected profile, where the master against which the work is to be checked must be produced quickly and cheaply.

Several types of face driving centres are exhibited by **Kosta,** of Stuttgart, Germany. This type of centre replaces chucking and other circumferential clamping, considerably reducing handling time and permitting components to be changed while the machine is running.



Furthermore, automatic centering and accurate turning to a stop are ensured, even if the component faces are sawn, forged, or at an angle to the axis.

As no faceplate and carrier are needed, components can be turned along their whole length without any necessity for re-clamping. Furthermore, as can be seen from the illustrations, centres are available with taper shanks or with flange mounting, which can be selected according to the spindle on which they are intended to be used.

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NEWS OF THE MONTH

PERSONAL

Mr. Robert Atkinson, D.Sc., R.D., B.Sc., M.I.Mar.E., has been elected a director of the Hamworthy Engineering Co. Ltd., Poole, Dorset, and of British Combustion Equipment Ltd. **Dr. N. A. Cheetham, B.Sc.,** has been appointed chief engineer of British Combustion Equipment Ltd.

Mr. J. E. Bagguley, M.I.Loco.E., has been appointed works manager of the Yorkshire Engine Co. Ltd., Sheffield. **Mr Rupert Lancaster** has been appointed general works manager of the Distington Engineering Co. Ltd., Workington, Cumberland.

Commander F. W. N. Bassett, R.N.(ret.), has been appointed commercial director of Normalair Ltd., Yeovil. **Mr. D. C. Collins** has been appointed works director, and **Mr. Oppenheimer,** finance director of the company.

Mr. G. W. Bone, M.I.Mech.E., A.F.R.Ae.S., has been appointed managing director of Davey, Paxman & Co. Ltd., Colchester, in succession to **Sir John Greaves.**

Rear-Admiral Sir Philip Clarke, K.B.E., C.B., D.S.O., has been elected President of the British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1.

Mr. W. R. J. Cook, C.B., M.Sc., Chief of the Royal Naval Scientific Service, has been released from his post to take up the post of deputy director of the Atomic Weapons Research Establishment, Aldermaston.

Mr. W. H. Dann, M.B.E., B.Sc., Wh.Sch., A.M.I.N.A., has been elected a director of Saunders-Roe (Anglesey) Ltd., Beaumaris, Anglesey.

Mr. P. R. Dunn, B.Sc., M.I.E.E., deputy chief engineer of British Insulated Callender's Cables Ltd., Past President of the North Western Branch of the Association of Mining Electrical and Mechanical Engineers and of the Manchester and District Branch of the Institute of Welding, has been elected Chairman of the Mersey and North Wales Centre of the Institution of Electrical Engineers.

Mr. P. E. Felgate, B.Sc., A.F.R.Ae.S., A.M.I.E.E., has been appointed chief development engineer (engine controls) at the Cheltenham factory of Smiths Aircraft Instruments Ltd. He was formerly chief development engineer of Waymouth Gauges and Instruments Ltd., Godalming, for which position **Mr. W. G. Smith** has now been appointed.

Mr. Ernest Haughton, A.M.I.Mech.E., has been appointed assistant city engineer (Mechanical) to the Corporation of Liverpool.

Mr. G. E. Hughes-Jones has been appointed manager of the Newcastle-upon-Tyne office of the Brush Electrical Engineering Co. Ltd., Loughborough.

Mr. J. F. B. Jackson, B.Sc., A.R.I.C., F.I.M., has relinquished his position as director of the British Steel Castings Research Association and has been appointed director in charge of the new foundries of A.P.V.—Paramount Ltd., Crawley, Sussex.

Mr. E. H. Jerrett, general manager of Cambrian Wagon and Engineering Co. Ltd., Maindy, Cardiff, has been elected a director of the Company.

Mr. S. E. H. Kewney, A.M.I.Mech.E., has been appointed a director and general manager of Andrew Barclay, Sons & Co. Ltd., Caledonia Works, Kilmarnock.

The Rt. Hon. Oliver Lyttelton, D.S.O., M.C., has been elected Chairman of the British Thomson-Houston Co. Ltd., Rugby, in succession to **Sir Felix J. C. Pole,** who relinquished his office as Chairman and has resigned his seat on the Board. **Sir George E. Bailey, C.B.E.,** has also resigned his directorship and has relinquished his office as deputy chairman of the company.

Mr. E. P. B. Metcalfe has been appointed engineer-in-charge of the new television transmitting station of the B.B.C. which is now under construction at Rowridge, Isle of Wight, and will come into service on November 12.

Mr. G. H. Passey has been appointed diesel traction engineer to British United Traction Ltd., Boreham Wood. He will be responsible for the design and development of B.U.T. diesel trains and associated equipment and for the management of the drawing office. **Mr. F. Hodgkinson** has been appointed to the engineering staff of the company.

Dr. W. H. Penley, A.M.I.E.E., has been promoted to the rank of deputy chief scientific officer to the Ministry of Supply and has been appointed senior superintendent, Guided Weapons, at the Radar Research Establishment, Malvern.

Mr. Stanley Robson, M.Sc., D.I.C., has been elected President of the Institution of Mining and Metallurgy, Salisbury House, Finsbury Circus, London, E.C.2, in succession to **Brigadier R. S. G. Stokes, C.B.E., D.S.O., M.C.**

Mr. C. E. Slade, M.Inst.W., has left the service of Philips Electrical Ltd. and has started practice at 11 Trowlock Avenue, Teddington, Middlesex, as consulting engineer specialising in resistance welding.

Mr. Kelvin Tallent Spencer, C.B.E., M.C., B.Sc.(Eng.), F.R.Ae.S., A.M.I.C.E., has been appointed by the Minister of Fuel and Power to the position of Chief Scientist to the Ministry, in succession to **Sir Harold Roxbee Cox, Ph.D., D.I.C., B.Sc., M.I.Mech.E.**

Mr. K. L. Stretch, M.A.(Cantab.), A.M.I.C.E., A.M.I.Mech.E., A.M.I.E.E., has been appointed works manager at Calder Hall, Sellafield, Cumberland, where the first atomic power station of this country is now under construction.

Mr. A. S. Taylor, at one time production manager of the Universal Engineering Co. Ltd., Nottingham, has joined The Wallace Attwood Company, management consultants, Chantrey House, Eccleston Street, London, S.W.1.

Mr. William Tomlin, works manager of The Power Plant Co. Ltd., West Drayton, Middlesex, has been elected a director of the company.

Mr. A. C. Vivian, A.C.G.I., M.I.C.E., F.Inst.P., until recently, project manager of the Llandarcy refinery expansion scheme of the Anglo-Iranian Oil Co. Ltd., has been appointed managing director of Metal and Pipeline Endurance Ltd., 4/24 Chandos Court, Caxton Street, London, S.W.1.

Mr. Charles Watson, for many years chief sales engineer of British Ermeto Corporation Ltd., Hargrave Road, Maidenhead, has been elected a director of the Company.

Mr. A. W. Welton, A.S.A.A., Chairman of The Radio and Electrical Trades' Guardian Association, a Freeman of the City of London, has been elected to the Board of Mullard Ltd. He is already a director of Mullard Overseas Ltd. and Mullard Wireless (Near East) Ltd.

Mr. John Wood has been elected Chairman of Charles D. Holmes & Co. Ltd., Hull, in succession to the late **Mr. H. E. Sheardown, C.B.E. Mr. Harry Smith** has been appointed managing director of the company, with **Mr. M. H. R. Brockman** as his personal assistant. **Mr. W. R. Evans,** manager, and **Mr. G. H. Hardy,** secretary, have been elected to the Board.

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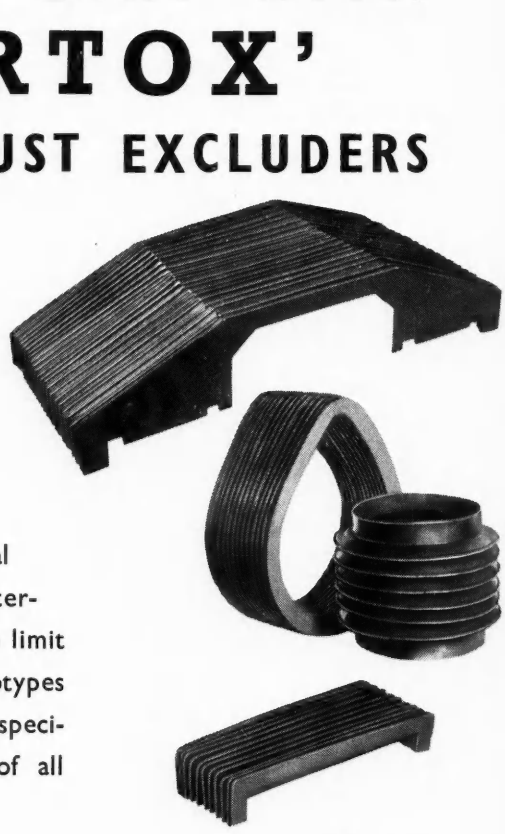

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BUSINESS NOTES

Davey, Paxman & Co. Ltd., Colchester, announce that their London office is now situated at 1 Balfour Place, Mount Street, W.1. Telephone: GRosvenor 6114/5. Mr. A. C. Parker is London manager of the company.

Rapid Magnetic Machines Ltd., Lombard Street, Birmingham 12, announce that an extension to their factory should be complete in six months' time.

A new Dunlop factory which will be additional to the existing factory at Queen Street, Toronto, and will cost more than 6,000,000 dollars, is being built at Whitby on the shores of Lake Ontario on a site of 56 acres, 28 miles from Toronto. The new factory will produce all types of tyres and also Dunlopillo latex foam.

From an area of 160,000 sq. ft. for tyre production it is expected that, beginning next spring, the output of car and giant covers will, by the end of 1957, be approximately 50% more than the present production, when this part of the factory will employ some 500 men and women. The tyre plant embodies the latest designs in moulding equipment and tyre building units. High efficiency, high horse power units will be installed, with fully automatic handling equipment for processing. Much of the major processing equipment is to be shipped from the United Kingdom along with the main electrical drive motors, the maximum individual unit h.p. being 1,000.

The Dunlopillo plant occupying 75,000 sq. ft. will similarly embody the latest developments in conveyorised moulding and sheeting production, and when completed production should be more than double the existing quantities now manufactured in the Toronto plant.

The factory is both sited and laid out with provision for future expansion.

The Directors of Permali Limited announce that, subject to the necessary consents being obtained, a merger has been arranged between the Company and Hordern-Richmond Limited.

Mr. Lawrence Robson, Chairman of Hordern-Richmond Limited, will join the Board of Permali Limited.

Permali Limited, whose shares were marketed in February last on the London Stock Exchange, are manufacturers of densified wood laminates and bakelised paper products, primarily for electrical insulating purposes, under the trade names " Permali " and " Dialam " and Hordern-Richmond are manufacturers of " Hydulignum " wood laminates and other products for the Aircraft, Textile and Engineering industries.

Mercast (Great Britain) Ltd., at Albert Street, Bilston, Staffordshire, a new company, has been formed by Guest, Keen & Nettlefolds Ltd. and the Mercast Corporation, of New York, to license manufacturers in the United Kingdom and other British Commonwealth countries (excluding Canada) to use the Mercast process of investment casting. In this process frozen mercury patterns are used instead of wax patterns, and it is claimed that closer tolerances and smoother finish can be achieved and larger and more complicated castings can be produced than by the use of wax patterns.

Mr. Christopher Dykes, M.A., M.S., M.S.A.E., M.A.S.M., aeronautical consulting engineer, has been appointed technical manager of the new company.

Powers-Samas Accounting Machines Ltd. announce that, owing to the large increase in sales of their products at home and abroad, it has become necessary to expand production, and negotiations are now at an advanced stage to take over additional capacity to be made available to it by Vickers-Armstrong Ltd.

Mr. Robert Wonfor has been appointed managing director (Sales, Finance and Research) and Mr. T. R. Swift managing director (Production).

Mr. F. G. S. English, hitherto in charge of Production, has been appointed production control adviser and, in addition, managing director of Powers-Samas Developments Ltd., a wholly owned subsidiary which will concentrate on the application of punched card methods to production control in industry. The office of Mr. English will be at 88 High Holborn, London, W.C.1.

Mr. Robert Wonfor has been appointed Chairman of Powers-Samas Developments Ltd. and Mr. F. J. Nash an additional director.

The Distillers Company Limited and the **Oronite Chemical Company,** of San Francisco, U.S.A., announce the formation of Orobis Limited, a jointly owned Company, now constructing a plant for the manufacture of lubricating oil additives at Hull.

A complete range of lubricating oil additives, as manufactured by Oronite in the United States, will be manufactured and marketed by the new Company. Facilities will include a fully equipped engine-testing and customer service laboratory. It is expected that the plant will be in operation early next year.

Brown Brothers & Co. Ltd., Rosebank Ironworks, Edinburgh 7, have concluded an agreement with J. M. Voith G.m.b.H., Heidenheim, Germany, for the manufacture, under licence, of the Voith-Schneider propeller and control equipment and for its supply within the British Commonwealth. Captain E. C. Goldsworthy, Estate Buildings, South Road, Weybridge, will continue to assist in liaison and sales.

Gas Purification & Chemical Co. Ltd., Palmerston House, Bishopsgate, London, E.C.2, have acquired control of Grundig (Great Britain) Ltd., Besson & Robinson Ltd., Smart & Brown (Machine Tools) Ltd. and Johnson British Electric Ltd. Extensive developments in the field of electronic engineering are contemplated.

Enthoven Solders Ltd., 89 Upper Thames Street, London, E.C.4, have been appointed sole distributors for the British Isles of the " Scope " soldering iron, developed by Scope Laboratories, of Melbourne, Australia.

The Renold and Coventry Chain Co. Ltd. have changed the name of the company to Renold Chains Ltd. The registered office has been transferred to new offices at Renold House, Wythenshawe, Manchester.

Edward J. Skinner Ltd. have opened a new factory at Lode Lane, Solihull, Birmingham, to provide increased space for the manufacture of special-purpose machine tools in larger sizes and increased numbers.

Tiltman Langley Laboratories Ltd, of Redhill, Surrey, have acquired control of Mid-Century Engineering Ltd., of Cranleigh, Sussex.

With the exception of Mr. V. C. Jessup, managing director of Mid-Century Engineering Ltd., the other directors of this Company have retired and have been replaced by Mr. M. Langley and Mr. L. D. Neeves, managing director and secretary respectively of Tiltman Langley Laboratories Ltd.

Tiltman Langley are extending the capacity of the Mid-Century factory. It is planned, during the next few months, to set up a new factory with considerably larger floor space and much additional equipment.

The Abbey Panel & Sheet Metal Co. Ltd., Old Church Road, Little Heath, Coventry, announce that increasing demand for their services in the field of sheet metal manipulation and fabrication has made it necessary to expand the manufacturing capacity of the company.

A new factory of concrete construction, which covers at present an area of about 14,000 sq. ft., has been erected by the Beacham Building Company. This new factory will be engaged entirely on the production of aircraft fabrications and assemblies. The new factory will function as the Aircraft Division of The Abbey Panel & Sheet Metal Co. Ltd., whilst the Motor Body Works of the Company will remain at Black Bank Works, Bedworth.

Mr. John Lund has terminated the manufacturing arrangements for the " Hydro-Tracer " profiling and copying valve which he had with Hayes Engineering (Leeds) Limited, and has joined the Machine Tool Division of Fairbairn Lawson Combe Barbour Limited, Leeds, to whom he has delegated all patent rights in respect of the copying valve with the object of developing profiling and copying equipment as conversions to existing machinery, special copying and profile machines and special machine tools generally.

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$$D\left(\frac{d\theta}{dx}+\frac{1}{m}\frac{\theta}{x}\right)=M_A$$

$$D\left(\frac{\theta}{x}+\frac{1}{m}\frac{d\theta}{dx}\right)=M_B$$

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BRANCH ESTABLISHMENTS AT ROCHESTER, WEYMOUTH AND BOREHAMWOOD

British Insulated Callender's (Submarine Cables) Ltd.—with an authorised capital of £250,000—has been formed by British Insulated Callender's Cables Ltd. and W. T. Glover & Co. Ltd. to specialise in the design and manufacture of Submarine Power Cables. The Registered Office of the Company is Norfolk House, Norfolk Street, London, W.C.2, and the Works are at Trafford Park, Manchester. During most of 1955 the Company will be occupied with the manufacture of approximately 77 miles of 138 kV 0·35 sq. in. Gas-filled Submarine Power Cable for the British Columbia Electric Co. Ltd. of Canada to the order received by British Insulated Callender's Cables Ltd.

Mr. W. H. McFadzean, C.A., is Chairman of the Company and the other Directors are Mr. C. O. Boyse, B.Sc.(Eng.), M.I.C.E., M.I.E.E., Fel.A.I.E.E., Mr. K. S. Brazier, B.Sc.(Eng.), M.I.E.E., M.I.Mech.E. (Works Manager), Mr. E. L. Davey, B.Sc.(Eng.), M.I.E.E. (Chief Engineer), Mr. R. M. Fairfield, B.Sc.(Eng.), M.I.E.E., M.I.Mech.E., M.A.I.E.E. (General Manager), Mr. W. C. Handley, B.Sc.(Tech.), M.I.E.E., Mr. D. T. Hollingsworth, M.I.E.E., and Mr. H. J. Stone, M.C., M.I.E.E. The Secretary is Mr. F. V. Thompson, F.C.I.S., A.A.C.C.A.

The Council of The Institution of Electrical Engineers will celebrate on November 16th, five years from the date of the application by Sir Ambrose Fleming for the British Patent for his thermionic valve, the jubilee of this invention. The Lord President of the Council, the Marquess of Salisbury will open the proceedings, and lectures will be delivered by Sir Edward Appleton, Professor G. W.O. Howe and Dr. J. Thomson on valves from the earliest developments to the present day. An exhibition of historical apparatus will be held at the Institution on the occasion of this celebration.

Filters on Space Heaters and Smoke Stacks. The maintenance of space heaters in The Timken Roller Bearing Company shop areas had presented a difficult and expensive problem. Heavy coats of both oil and dust were deposited on the various parts of the space heater, creating a serious maintenance and cleaning problem. Three or four times each year each heater had to be dismantled and cleaned with steam.

This expensive and time-consuming maintenance problem has been solved by installing a permanent impingment type air filter at the back of each space heater. Housed in a sheet metal box, two impingment filters were installed in the housing affixed to the back of the heater. The two filters can be removed periodically, placed in a washer, and in a matter of minutes, reinstalled in the sheet metal housing. The tedious, expensive task of dismantling and cleaning each space heater has thus been eliminated.

One hundred such installations have been made at the Canton and Gambrinus plants of The Timken Roller Bearing Company. The filter installations will pay for themselves in less than a year as a result of the marked reduction in required maintenance.

A similar filter installation has been made on the flues and smoke stacks in the roller hardening department, where carbon particles and oil were deposited in the ducts and smoke stacks creating a potentially dangerous fire hazard. Annually a maintenance crew would laboriously clean each duct and each smoke stack. The new filter installations will not only eliminate the necessity of cleaning these stacks each year, but also will greatly improve the safety factor in that department.

Compressed Air Vessels of Reinforced Plastics which store air at the highest projected pressures for aircraft pneumatic systems are announced by Dunlop Aviation Division which regards the new containers as an important contribution to the solution of some of the problems of storing air at the high pressures demanded by modern aircraft pneumatic systems.

They are made of layers of glass fibre impregnated with a synthetic resin. The fibre is non-alkaline and relatively unaffected by moisture: the resins are selected to achieve the most efficient bonding for any particular application. The tensile strength of the glass fibre is superior to that of other plastics or metals and the new bottle has a much improved strength/weight ratio over the usual container. It is lighter and stronger than the metal type and of equal physical performance to it.

The weight saved is about 33 per cent and the orientation of the fibre layers result in much less strength "scatter" and more accurate ultimate pressures. Resistance to temperature and weather is extremely good and, being shatter-proof, the containers are safer. Bullets and other missiles do not splinter them and they are therefore, apart from aviation, a highly practicable proposition for naval and military purposes.

"Grain flow," a special weakness of metal air bottles, is completely absent from the reinforced plastic component. Fatigue life is very good and the containers can be readily made in spherical shape in any capacity or strength for any design. Special applications for gases other than air can also be considered. The containers are superior to the usual metal types in dielectric properties and in resistance to chemicals and corrosion.

Cooled Stator Blades for Gas Turbines. Henry Wiggin & Co. Ltd., Wiggin Street, Birmingham 16, have been producing for some time Nimonic alloy aerofoil sections by hot extrusion and subsequent rolling. The extrusion process extends the range of composition of alloys which can be commercially worked by breaking down the coarse structure of the cast ingot and thus improving forgeability so that ordinary hot- and cold-working operations can be used to give the desired final dimensions. Work is now sufficiently advanced to enable a wide range of such forms to be successfully extruded, including those containing various configurations of cooling passages.

Cooled blade sections are produced in Nimonic 80A and Nimonic 90, offering all the characteristics of these alloys for applications where resistance to oxidation and thermal shock is required, but making these properties available for service with still higher gas temperatures, with consequent improvement in overall output and efficiency.

A REVIEW OF PROGRESS IN THE BRITISH DIESEL LOCOMOTIVE INDUSTRY

Diesel locomotives are replacing steam engines on railways throughout the world.

The British diesel locomotive industry, which has expanded considerably since the war, is busy with orders not only for railways but for factories, ports, quarries and other industrial users.

Nevertheless, in this country it faces many difficulties. Some of the ways in which manufacturers are tackling them are the subject of "The Wheels of Progress: A Review of Productivity in the Diesel Locomotive Industry," published by the British Productivity Council.

One of the main problems confronting manufacturers in this country is that large main line diesel locomotives are produced almost entirely for export. Only the smaller industrial types find a market in Britain and, even of this class, more than half of the total production is sold overseas.

Because of this, complete standardisation is almost impossible in a large proportion of the British industry. British diesel locomotives are, in the main, "tailor-made" to suit the requirements of individual customers. This hinders the introduction of modern flow methods of production.

Despite this problem, a shortage of skilled labour and, among many firms, the handicap of premises not offering full modern amenities, manufacturers in this country have done much in recent years to improve their efficiency.

The Review reports how basic componetns have been standardised for locomotives of different overall design; how production planning systems have been evolved; how the principle of unit construction—building complete sections such as cabs and bodies in entirety before the assembly of the complete locomotive—is gaining ground; and how welding techniques have been improved.

Copies of the Review are obtainable, price 2s. each, net, from the BRITISH PRODUCTIVITY COUNCIL, 21 Tothill Street, London, S.W.1.

TEAM REPORT ON INDUSTRIAL ENGINEERING

"Industrial Engineering" is the subject of the last of the Reports of the series of British Productivity Teams that have visited America. It is illustrated with drawings by Nicolas Bentley.

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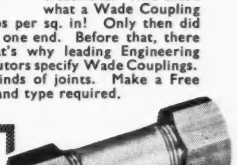

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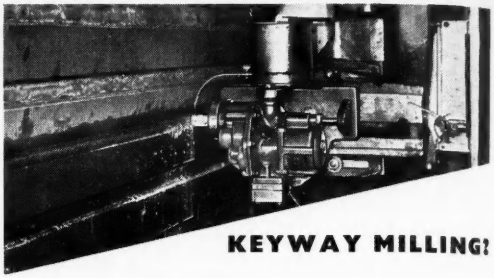

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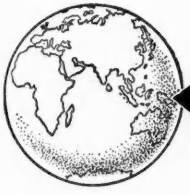
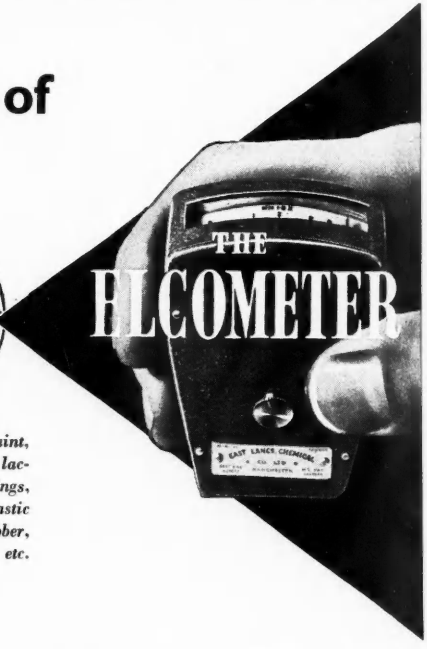


★ *Measures: paint, porcelain enamels, lacquer, tinnings, platings, metal sprays, plastic sheetings, leather, rubber, foils, concrete, glass, etc.*



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which was originated by the A.A.C.P., gave them a particular authority, and has subsequently been adopted by many other countries.

The Industrial Engineering Team, which visited the U.S. in 1953, was given the most comprehensive brief of all: "To investigate the dynamic and aggressive American approach to improvement of methods of manufacture and to continuous reduction of operating costs." It has not always been clear why managerial techniques, already well known in Britain, are applied so effectively in the U.S. The Team tried to find out what was the source of the American drive to cut out waste.

Its members had a broad range of knowledge, being nominated by the D.S.I.R., the Engineering and Allied Employers' Federation, the T.U.C., the British Institute of Management, the Institute of Cost and Works Accountants, the Institution of Production Engineers and the Ministry of Education. Their Report was unanimous.

The Team found three factors of over-riding importance:

(1) The sharp and urgent competitiveness of the U.S. economy;

(2) The ever-present cost-consciousness among all ranks in industry and commerce, and the rapid marshalling of cost figures;

(3) The concerted application of modern managerial techniques by the industrial engineer.

The Report discusses them in relation to financial budgeting and control, design, planning and control of production, utilisation of research, plant layout, materials handling, time study, motion study, tool design, incentives, job evaluation and industrial relations; it also considers appropriate training for the industrial engineer.

Interest will focus on the new concept of the industrial engineer. They dub him "architect of productivity." "His job is to bring together the scientists, technologists and others to promote productive efficiency." His purpose is to bring clarity and purpose to the diverse techniques that can contribute to productive efficiency.

The Team is convinced that the more intensive and universal use of modern managerial techniques in the U.S. is largely attributable to the acceptance and steadily increasing employment of industrial engineers.

LIGHTING TRUNKING IN A MACHINE TOOL FACTORY

A fluorescent installation comprising 1,220 fittings supported from overhead trunking has been brought into use recently at the Leicester factory of Jones & Shipman Limited, makers of precision grinding machines. An average service illumination of 24 lumens per sq. ft. is provided over an area of 90,000 sq. ft.

Overhead trunking accommodates the wiring to lighting fittings, which may be attached to it at any desired spacing. Trunking is erected ready wired, the only connections to be made after it is in position being those for the cables feeding each control gear position. Wiring for other services, such as telephones or public address equipment, can be run similarly through the trunking, with benefit to the appearance and convenience of an installation.

At the Jones & Shipman factory, for which the equipment has been supplied by The General Electric Co. Ltd., the trunking is arranged transversely; each run, generally of 220 ft., rests at its ends on brackets in the side walls and intermediately on the roof trusses. These supports allow longitudinal expansion, but transverse movement is prevented by U-shape clips on alternate trusses.

The fittings are vitreous enamel reflectors, as the presence of abrasive dust in the atmosphere made it necessary to choose a finish that can be cleaned easily. The reflectors are slotted to provide upward illumination. Each accommodates one Osram 5 ft. 80 W. Daylight fluorescent tube. The chokes, capacitors, and starter switches are housed inside the trunking, and are accessible by removing cover plates. Tubes are connected in the twin-tube circuit to improve the power factor and minimise stroboscopic effect.

In general the fittings are mounted continuously, but where the runs are over gangways, two out of three are omitted. Mounting height is 12 ft 6 in., and the runs of fittings are 10 ft 6 in. apart throughout the shop, which is 504 ft. long.

The lighting scheme was planned and designed jointly by Mr. H. Walker, A.M.I.E.E., of the Electrical Equipment Co. (Leicester) Ltd., London Road, Leicester, and Mr. L. A. B. Lowe of Jones & Shipman Ltd.

The Canadian Trade Index is one of the Canadian Manufacturers' Association's many valuable services for Canadian business and its customers at home and abroad. About one-third of the yearly circulation of the Index goes to readers in Canada's export markets all over the world.

The 1127-page 1954 edition of the *Index* gives essential details of some ten thousand manufacturing firms in Canada, as well as a classified directory of many thousands of manufactured products listing the firms making them—a valuable buyers' guide which is supplemented by hundreds of illustrated advertisements. The directory of products includes a cross-reference index in French, while limited editions have Spanish and Portuguese indexes for convenience to the Latin-American trade. A special export section provides readers with useful information on export methods and services, including articles on markets, export pricing, financing, insurance, shipping and documentation.

The Canadian Trade Index is available from the Canadian Manufacturers' Association, 67 Yonge Street, Toronto 1, Ontario, at $7.50 per copy, post paid.

BRITISH STANDARDS

Copies of British Standards may be obtained from the British Standards Institution, 2, Park Street, London, W.1.)

Manufacture and Testing of Refrigerating Cabinets ("Reach in" type)—B.S. 2501 : 1954 ("Walk in" type) B.S. 2502 : 1954. The two new standards are intended to make provision for larger commercial and industrial refrigerators, viz., cabinets of 12 to 100 cu. ft. net capacity, and sectional cold rooms of 100 to 1500 cu. ft. gross capacity. Price 3/- each.

Data Sheets for Limits and Fits (B S 1916C and B S. 1916D). Following on the publication of B.S. 1916, Parts 1 and 2, the British Standards Institution now present data sheets giving primary and secondary selections of fits extracted from the main Standard.

It is considered that the simple selection of six fits given in sheet 1 will meet the needs of a large proportion of the requirements of normal engineering products.

The five fits given in data sheet number 2 supplement the primary selection and it is thought that the two sheets will, between them, cover about 95 per cent of the fits used in average good quality engineering.

The sheets have been issued in the form which, it is hoped, will be most serviceable to drawing offices, and standards departments and designers are urged to give first consideration to these restricted selections of fits wherever possible, since concentration on a limited number of fits, coupled with the use of preferred sizes, will greatly facilitate the introduction of standard tools and gauges.

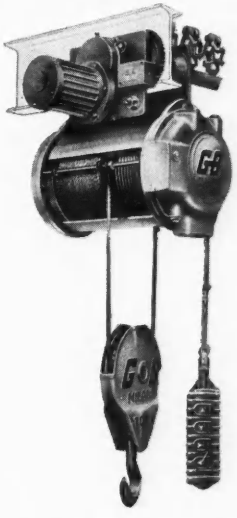
Automatic Controlling and Regulating Systems. B.S. 1523 : 1954, Sections 3 & 5. Section Three covers the terms used in kinetic control systems, i.e. systems for controlling the displacement, velocity or acceleration of a mechanical load, such as a crane, a die-sinking machine, or a gun; it therefore includes terms associated with servo-mechanisms.

This Section includes terms covering basic principles, feed-forward and feedback types of control systems, parts of a servo system, types of servo-mechanisms, types of continuous control action, and the performance of control systems. In defining a monitored control system, notes are given setting out the difference between a closed loop system and a system with a closed sequenc of dependence.

An appendix is included giving the effects of derivative and integral controls in a displacement-displacement kinetic control system for a load possessing inertia and viscous friction.

Section Five defines many of the terms which relate to the mechanical and electrical devices used in the building up of servo-systems—particularly those dealt with in Section Three—and covers devices used for deviation measurement, amplifiers and their components, computing devices, stabilizing and response-modifying devices, servo-motors and tachometers.

Transductors, which are important components of magnetic amplifiers, have been fully dealt with to meet the other growing



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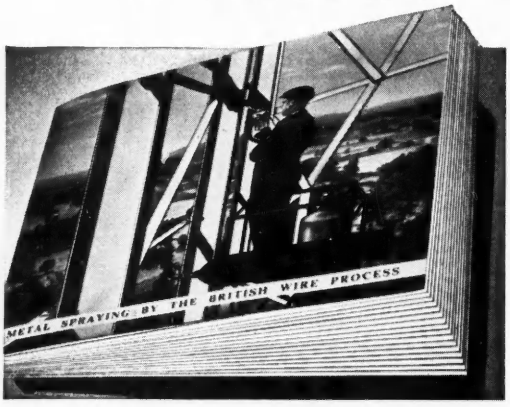

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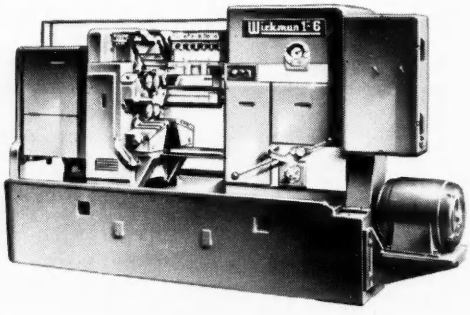

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uses of these devices; their definitions have been made clearer by the inclusion of diagrams showing the various arrangements of windings.

Important components of servo-mechanisms are synchros and their various modificationsk which are known by a variety of existing proprietary and descriptive names. The difficulty of dealing with these has been solved by the inclusion of an appendix which compares the "Standard" terms with names of existing variations and gives some details of the latter in respect of the number of their winding paths and their energy transfer systems.

Each Section is comprehensively indexed. A distinction is drawn in the Glossary between preferred and deprecated terms The deprecated terms are included in the index, so that the preferred term may be readily found. Price 3/- for Section 3 and 5/- for Section 5.

Vulcanized Extruded Rubber Compounds and Tubing. B.S. 1155 ; 1954 replaces the War Emergency Pamphlet published in 1944 and the earlier Government Department Specification T.G. 49, on which it was based.

The new standard revises and extends the scope of the original T.G. specification and specifies vulcanizates which are primarily intended to meet the requirements of Government Departments for many of their ordinary items in the form of tubing, and goods made by extrusion.

It covers four white and six black vulcanizates which are classified according to their hardness and gives skeleton compositions, physical tests and examples of typical compositions. Additionally it provides dimensions and tolerances for plain tubing made from these compounds. Price 2/6.

Impregnated Paper-insulated Cables for Electricity Supply. (B.S. 480 : 1954). This revision is in two separate, self-contained, parts :—

Part 1 : Lead or lead-alloy sheathed cables for working voltages up to and including 33 kV.

Part 2 : Aluminium sheathed cables for working voltages up to and including 22 kV.

Each part now contains "quality" clauses dealing with the composition of the various components of the cable. A basic reference temperature of 20° C for the properties of annealed high conductivity copper has been adopted. The practice of specifying minimum and maximum diameters over sheath and overall has been abandoned in favour of nominal diameters. Cables which comply with the requirements for minimum thickness of insulation and sheath will have the stated nominal diameters, which allow reasonable manufacturing tolerances.

Tests are now divided into acceptance tests and sample tests. The former consist of the conductor resistance and voltage tests, as in previous editions, with a dielectric power-factor/voltage test for 33 kV cables only. Bending and drainage tests are specified for use when required as sample tests and the voltages to be applied after the bending test have been increased for working voltages up to and including 11 kV. A physical examination of the test sample after the bending test is now specified, with the intention of accumulating data for a future revision of the standard. The bending test for aluminium sheathed cables requires two cycles of operations compared with three for lead sheathed cables. Test voltages for application after installation are the same for both types of cable.

Part 2 applies only to cables with swaged seamless aluminium sheath for working voltages up to and including 22 kV. Such cables, owing to the comparative hardness of the sheath, are not generally required to be armoured but, for special conditions where armouring is considered necessary, dimensions are specified. Price 6/- (Part 1) and 5/- (Part 2).

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HYDRAULIC AND MECHANICAL LEATHERS.—Capable man having good knowledge of engineering industry is required as representative in London area. Applicants should have good education and be conversant with the latest developments. Sound practical experience essential. Good prospects. Write stating age and experience to Box No. 125.

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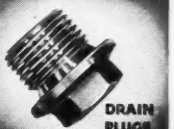

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BOOKS RECEIVED

Handbook of Aeronautics, No. 2: Component Design. 4th Edition, 1954. 216 pp., 124 illustrations. Published under the authority of the Council of the Royal Aeronautical Society by Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price: 30/-.

This is the second in the series of volumes comprising an entirely new edition of Pitman's "Handbook of Aeronautics."

This new edition of the Handbook has been radically transformed, to meet present-day requirements of industry. Six authorities have contributed to its writing. Its eight parts cover the construction and principles of design of aircraft structures, and the design and operation of the various component parts—landing gear, air-conditioning and pressurisation systems, control systems, power-actuating systems, and fuel systems. The subject of weight estimation and control is also given full consideration.

Anti-Friction Bearings. By Hudson T. Morton, B.Sc.(Eng.). 400 pp., over 400 illustrations. Publisher: Hudson T. Morton, 815 Wildt Street, P.O. Box 355, Ann Arbor, Michigan, U.S.A. Price: $7.75.

This completely modern textbook covers all important facts concerning anti-friction bearings, providing up-to-date information on a very wide range of pertinent subjects, including bearing designs, types, capacities, applications, load computation, and selection. In addition, there are useful sections devoted to bearing mounting and installation, identification codes, lubrication, and tables of sizes and numbers. Interesting chapters on the history of bearings are also included.

The author, who is now President and General Manager of the Morton Bearing Company, of Ann Arbor, Michigan, has served on numerous engineering committees for standardisation and research, and has also published several articles on metallurgy, lubrication, and bearing standards.

The information in this interesting publication was compiled by the author with the help of leading engineers in the bearing industry, and, though presented simply and concisely, is complete enough for machine designers, engineers, and bearing users, for all of whom it should undoubtedly prove a valuable reference manual.

Stainless Iron and Steel. *Vol. 2: Microstructure and Constitution.* 3rd Edition, 1954. By J. H. G. Monypenny, F.Inst.P.; edited by Professor F. C. Thompson, D.Met., M.Sc. 341 pp., 173 illustrations. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 55/-.

When the preparation of this new edition was under consideration, it was realized that the adequate description of modern developments would best be served by the publication of such an edition in two separate parts. Accordingly, this edition is now published in two volumes, sub-titled *Stainless Steels in Industry* (issued in 1951) and *Microstructure and Constitution*, respectively.

This second volume deals essentially with the metallography of the stainless and heat-resisting steels. Consideration is given to the constitutional diagrams of the iron-chromium alloys, both with and without carbon, and to the microstructures of the chromium steels and the effects thereon of variations in composition and heat treatment. The effects produced by the addition of other elements, such as manganese, nickel, silicon, aluminium, molybdenum, and tungsten on the properties of chrome-nickel steels are also considered. This leads to a discussion on what is known regarding the structural diagrams of the iron-chromium-nickel, the iron-chromium-manganese, and other complex iron-chromium alloys.

Though intended primarily for the metallurgist, this book will also benefit those who have not made a special study of the metallography of the alloy steels.

Worked Examples in the Theory of Machines. By R. McVie, B.Sc.(Eng.), A.M.I.Mech.E., A.M.I.E.E., M.I.Mar.E. 180 pp. 85 illustrations. Publishers: Hutchinson's Scientific and Technical Publications, Stratford Place, London, W.1. Price: 12/6.

The object of this book is to give guidance in the application of fundamental principles to the solution of problems, examples of which have been so chosen as to give as wide a cross-section as possible, and to illustrate the method of attacking a large variety of problems.

The book shows how to set down various steps in the working of problems clearly and logically, and its scope is intended to cover the major syllabuses of the major professional institutions, the Higher National Certificate, and Part I of the London University B.Sc.(Eng.) degree. The meanings of the various terms and symbols used are summarised at the beginning of the book, and are generally in accordance with the recommendations of the British Standards Institute.

Electric Power Stations. *Vol. I.* 4th Edition, 1954. By T. H. Carr, M.I.C.E., M.I.Mech.E., M.I.E.E., M.I.F. 621 pp., 316 illustrations. Publishers: Chapman & Hall, Ltd., 37 Essex Street, London, W.C.2. Price: 70/-.

Power-station design calls for a wide knowledge of almost every branch of engineering, particularly with regard to the electrical, mechanical, and civil sections. This book deals with the general principles governing design, construction, and operation, and should undoubtedly prove useful to power-station engineers, consulting engineers, designers, and students.

This new edition has been revised and brought up to date, while a considerable amount of new material has been added. Vol. I covers station design, works and building, circulating water systems, cooling towers, coal-handling plant, ash-handling plant, boiler plant, pipework, and turbines. The 4th edition of Vol. II, which is in course of preparation, will cover the remaining aspects of the subject, including hydro-electric and diesel-electric plants, gas-turbine plants, and wind, atomic, and other power plants.

LATEST INDUSTRIAL LITERATURE

1. Lathe Cabinets. Details of a comprehensive range of lathe cabinets are contained in a neatly presented and illustrated loose-leaf brochure. Special attention has been paid to rigidity in the design of these cabinets, which are constructed of heavy-gauge sheet steel and stiffened at essential points by steel sections.

The standard finish is grey primer, to enable the user to apply a finishing coat to match the lathe; if required, however, a finishing coat can be applied as an extra. Furthermore, mountings for the lathe can be fitted at extra cost to the top side of the lathe tray.

A supplementary brochure describes and illustrates a wide range of fabricated sheet-steel cabinets for various purposes.

2. Earthing Equipment. An efficient earthing arrangement is an essential part of practically every electrical system and installation, to guard against the effects of leakage currents, short circuits, static charges, or lightning.

A well-produced and illustrated 40-page publication describes a comprehensive range of electrodes, bonding conductors, and ancillary earthing equipment, together with design and installation requirements for typical applications.

A supplementary publication describes a range of cotton, rubber, and thermoplastic insulating and protective tapes for a large variety of applications.

3. Earth-Moving Machinery Lubrication. Earth-moving machinery is, by its very nature, exposed to the effects of climate, mud, dirt, dust, and water. An 85-page book, well conceived and lavishly illustrated, gives a wealth of information which will undoubtedly be of great value in helping to improve the care, maintenance, and lubrication of this type of equipment.

Chapters are included on bearings; gears and transmission; wire ropes and lifting chains; hydraulic and pneumatic equipment; petrol, paraffin, and diesel engines; running gear; storage of equipment; maintenance; and lubrication.

4. Power-Plant Superheaters. A beautifully produced and illustrated 72-page publication has been issued by a company which has specialised in the design and manufacture of steam superheaters for over forty years, during which time it has played a leading part in stimulating progress in the field of steam generation by improvements in design, construction, and performance of superheating equipment.

In addition to chapters on considerations affecting superheater design, construction, and performance, and on steam temperature control, this publication describes and illustrates a large number of representative designs of superheaters for water-tube boilers.

5. Centrifugal Pumps. A range of reliable and economical pumps, suitable for handling highly abrasive substances, such as sand, gravel, or ash in water, is described and illustrated in a 16-page brochure.

These pumps are equally suitable for corrosive liquids or for fluids which are both abrasive and corrosive, the pump being expressly designed to prevent metallic contamination of the liquids inside the pump. In those rare cases where the special rubber lining is unsuitable, chemically-resistant synthetic linings can also be provided.

6. Hard-Facing Alloys. Details of a range of hard-facing alloys are contained in a profusely illustrated pamphlet of 12 pages. These alloys are available in various forms, such as oxy-acetylene rods, electrodes, paste, powder, wire, and castings, and are extremely hard, stable, and corrosion- and temperature-resistant. Furthermore, they have excellent weldability, hot hardness and galling resistance, and a low application melting point.

Also described in this, and in a supplementary, pamphlet is a powder metal-spraying unit, with a wide variety of applications.

7. Press-Feeding Equipment. Details are contained in a 4-page pamphlet of a universal power-press feeding device with several interesting and practical features. In this equipment, the feeding slide can be readily moved to any position on the press by manually bending the single, hydraulically loaded tube. The feeding slide may be mounted on the stock reel, independently of the press table, or without the stock reel and clamped directly to the press table. The stroke of the slide has infinite adjustment between zero and 3 in., and accuracy is $\pm 0{\cdot}002$ in. on stock in good condition.

Other features include a tappet release which frees stock for pilots to handle thin material; a tappet bar which opens the gripper, permitting easy insertion of material sideways; and visual indication of the pitch selected, with provision for making fine adjustment.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *FRETTING CORROSION*

According to recent investigations, the mechanism of fretting corrosion includes a chemical as well as a mechanical factor. Asperity rubbing on a metal surface is considered to produce a track of clean metal, which immediately oxidises or upon which gas rapidly adsorbs. The next asperity wipes off the oxide or initiates a reaction of the metal with the adsorbed gas, to produce oxide. This constitutes the so-called chemical factor of fretting. In addition, asperities dig below the surface, causing a certain amount of wear by welding or shearing action, in which metal particles are dislodged. This is the mechanical factor of fretting. It is now believed that the metallic debris produced by fretting does not oxidise spontaneously, as suggested by the molecular-attrition theory, but is partially converted to iron oxide by the secondary fretting action of particles rubbing against each other or against adjacent surfaces. This is claimed to account for the fact that ferric oxide is found by X-ray examination to be the major corrosion product, while metallic iron is present in only very small amounts. When investigating the fretting corrosion of mild steel, the humidity of the ambient air was found to be an important factor. This fact was first discovered through discrepancies in weight-loss data obtained in winter and summer respectively. It was ascertained that the fretting corrosion of mild steel in moist air is only 55 to 65% of the weight loss in dry air, depending upon the length of the test. At the same time, it was observed that fretting corrosion is appreciably greater with lower temperature, the loss at 0° C being twice that incurred at 50° C.

● *SURFACE-HARDENING METHODS*

The use of surface-hardened steel parts has increased rapidly in recent years. This is due to the fact that steel users who require better-wearing materials for special purposes have found that a hardened surface often provides the kind of properties they need. Induction hardening was first carried out some twenty years ago. More recently, however, ceramic gas-burner installations and hardening machines which burn oxy-acetylene gas have been developed for this purpose. Conflicting claims have been made concerning the quality of surface hardening as performed by the three methods. Most of the questions with regard to quality concern the thickness of the case or hardened layer. Induction heating can give a hardness depth as shallow as 0·06 in. or even less. Ceramic burners, at the other end of the scale, give a minimum case depth of 0·125 in. The hardness depth resulting from an oxy-acetylene hardening machine is intermediate between these two figures. In order to assess the merits of the respective claims made for the specific advantages of the three methods, a special study was recently made, the findings of which can be summarised as follows :—No detectable distortion of heat-treated parts was found to be caused by an increase in the thickness of the case ; no differences in mechanical behaviour between induction- and flame-hardened specimens could be detected ; very shallow hardened zones in surface-hardened parts appear to have no particular merit ; grain size does not appear to have any significant effect upon the mechanical properties of the hardened layer. It was concluded that, from the aspect of mechanical properties, there is no choice between these three surface-hardening methods, except that thin-walled parts can be surface-hardened by induction heating only.

● *HIGH-DAMPING MANGANESE-COPPER ALLOYS*

Structural failures of machine members in service are generally caused by dynamic forces which are exerted in a member at or near resonance. These failures can be prevented if the excited forces are kept low ; this can often be attained by selecting members with sufficiently large damping. A high damping means that the excited vibrational energy is absorbed in the material before the vibration can build up. Internal damping, therefore, is an important property of machine members. Despite its significance, very little is known about its evaluation. In general, the internal damping of a complicated component part may be determined in two ways, i.e., the particular part may be used as a specimen and tested under conditions analogous to the operating conditions, or the damping may be measured in a conventional way on a specimen of simple shape, and the results of this test may then be used to derive the internal damping of the complicated part. For cases in which operational noise must be combated, high-damping alloys for machine and structural components have been developed. Certain of these alloys contain 60 to 80% electrolytic manganese, the balance being copper. When heat-treated,

400 per cent dividend in the first year : as Fibreglass Rigid Sections are **AVAILABLE FROM STOCK** you can start reaping such benefits at once. Write for our booklet now. An uninsulated 3-inch main, 100 feet long, carrying steam at 400°F wastes fuel at the rate of 13.8 pounds every hour—54 tons in a year of 8,000 working hours. Insulated with Fibreglass Rigid Sections, 2-inches thick (with fixing the cost is about £50) the loss is reduced to 4 tons of coal a year — a clear saving of 50 tons — a sheer gain of £200. Fibreglass insulation is paying 400 per cent dividend in the first year.

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the material exhibits a considerable damping capacity, while at the same time the strength properties of the material are comparable with those of structural steel. The specific damping capacity of the material is given as 35%, where specific damping capacity represents the percentage of total vibrational energy absorbed per cycle of vibration. For comparison, grey iron, generally considered a suitable alloy for applications requiring good vibration damping, has a specific damping capacity of less than 8% under similar test conditions.

● *MAGNETIC CLUTCHES FOR AUTOMOBILE AUXILIARIES*

In the modern motor car and lorry, a considerable amount of engine power is used for driving auxiliaries such as fans, generators, and sometimes for air-conditioning equipment. The loss in tractive power may therefore amount to well over 20% of the engine power—not counting power-transmission losses. In the case of fans, these should be driven only when the engine temperature exceeds certain limits; there is consequently no need to drive a fan during the warming-up period of the engine or under most operating conditions, except perhaps for driving in traffic or during other low-speed driving periods. Since the power absorbed by the fan increases as the cube of its speed, the desirability of eliminating an unnecessary waste of fan power is obvious. With respect to generators, for the most part these need to be run regardless of the speed of the vehicle, but their speed should remain approximately constant as engine speed is increased. Air-conditioning systems should deliver about the same amount of conditioned air, irrespective of engine speed, and compressor overspeeding at high engine speeds should be prevented for the sake of efficient operation and long compressor life. A simple, reliable clutch for disengaging the auxiliaries when not needed, or for effecting a speed reduction, when called for, is therefore clearly desirable. A special clutch of the powder-magnetic type has now been introduced and is claimed to hold considerable promise. In the case of the fan drive, this clutch is controlled by engine temperature, and it is claimed that, in addition to the saving in power, it permits the engine to warm up more quickly and to promote its quiet running.

● *X-RAY MICROSCOPE*

The recently announced development of an X-ray microscope capable of producing X-ray images with magnifications up to 1500 diameters opens up a host of new possibilities for research in a variety of fields. This instrument should prove a valuable aid in the development of new alloys and in the study of problems of corrosion and welding. Preparations are being made to use this new tool for studying the covering or bonding quality of paints, adhesives, and finishes, and it is expected that in some cases the X-ray microscope may provide a speedy substitute for chemical analysis. In all these investigations, the X-ray microscope will reveal the mixture of substances present, as, for instance, in alloys and plastics, and will identify the individual constituents by their relative X-ray absorbing power. Perhaps even more important and far-reaching findings may be made in the medical field, when X-ray microscopy is applied to such problems as tooth decay, diseases of the bones, mineral deficiencies, and hardening of the arteries. In heredity studies it will now be possible to study changes in the internal organs of the fruit flies used in these investigations. The X-ray microscope operates on the projection principle, the magnification depending on the ratio of the distance between image and X-ray source to that between object and X-ray source. In order to obtain a sharp image, it is necessary to provide a point X-ray source and the degree of sharpness obtainable in practice therefore depends upon how small this source can be made. In the new instrument, the X-ray source is only one 1/100,000 in. in diameter; this is achieved by passing the electrons through two electrostatic lenses. As the wavelength of X-rays is a function of the voltage applied, it can be varied without changing focus, and it is thus possible to vary the contrast of pictures.

● *SULPHURISED TOOL STEEL*

It is claimed that a sulphurised tool steel, when used as a gear-hob material, prevents tearing and produces better surface finish. The steel in question is a tungsten-molybdenum, high-speed steel containing approximately 0·1% sulphur. To make this material, sulphur is added during the alloying process, but definite information of the exact nature of the alloy sulphides produced in the steel has not as yet become available. It is further reported that sulphide additives in steels of the high-chromium type improve machinability, and it is claimed that a 1·5% C, 12% Cr steel can be machined up to 100% more quickly, if it contains the sulphide additive. It is, however, admitted that it is too early to draw any conclusions on increased tool life. With regard to the possible effect of the sulphide additive on heat treatment and mechanical properties, no change, compared with non-sulphur tools, was found. Moreover, a metallurgical report states that grain size, impact strength, cutting-edge strength, traverse bend, tensile strength, and ultimate strength are not affected by the sulphide content. In spite of these optimistic reports, it would appear advisable to withhold judgment until more tangible proof of the superior properties of the new steel becomes available. However, a patent on sulphur addition to high-carbon, high-chromium steel was taken out more than ten years ago.

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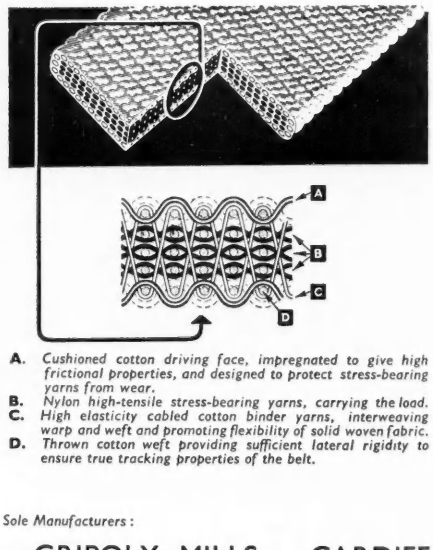
are incorporated by a special weaving technique which involves pre-stressing the nylon core and locking it by means of a thin cotton envelope of high frictional properties.



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● *PLASTIC-COATED HEAT-EXCHANGER COILS*

It is well known that coils for heating corrosive solutions are frequently subjected to more drastic changes in temperature, thermal stress, and agitation than tanks, pipe lines, and other equipment. Moreover, many of the materials available for heat exchangers designed for corrosive conditions, such as glass, are fragile, while others are extremely expensive, and the remaining materials are restricted in their applications. It is difficult, therefore, to find an economical material for heating coils which can be used in severely corrosive solutions. One solution which is said to have given satisfaction in numerous cases is the application of a coating of fluorocarbon plastic material to common metals. Two of these plastics are reported to be resistant to many corrosives at temperatures up to 400° F. The monochlorotrifluoroethylene polymer, for example, has been used to apply coatings, up to 0·2 in. in thickness, which proved free of pinholes and flaws. As the interiors of the tubes are necessarily unprotected, only steam and non-corrosive heat-carrier fluids may be passed through these tubes. Initially coatings of only 0·005 in. in thickness were used, presumably in order to keep the loss in heat transfer owing to the coating to a minimum. It was, however, found advantageous to increase the thickness of the coating to 0·2 in., so as to lengthen the service life of the tubing under corrosive conditions. Coatings of both thicknesses have been tested for flaws and pinholes by means of a 30,000-V spark source. Where the unavoidable, but not excessive, loss in heat-transfer efficiency and the limiting temperature of 400° F are acceptable, plastic insulated tubing may provide a solution, but the brief service life, although longer than that of competitive equipment, will of course have to be accepted.

● *WELDING OF PLATINUM TO MILD STEEL*

The welding of platinum to mild steel and to other metals with a melting point lower than that of platinum is known to present very great difficulties. These, of course, are due to the wide difference in the melting points of the platinum and the other metal and to their respective coefficients of expansion. It has now been found that an efficient ductile weld can be produced between platinum and steel, nickel, or any other metal with a melting point below that of platinum, by forming between the platinum and the other metal a layer of the other metal, enriched in chromium by diffusing chromium into its surface at the location where the weld is to be made. This diffusion of chromium can be carried out by a variety of methods. Thus, for instance, the metal part to be treated can be packed in powdered chromium or in a mixture of powdered chromium and alumina. A temperature of 1300 to 1400° C is then maintained for three or four hours in the presence of hydrogen. This will produce a diffusion layer of the thickness required. It is claimed that the welding process, which is patented, is particularly useful for making the central electrode of spark plugs for internal combustion engines. In this case the actual welding process is carried out by resistance welding, the two metal parts being pressed against each other during passage of the electric current. It is claimed that the chromising process leaves the piece sufficiently ductile to permit it to be worked into the required shape and that, if the piece is chromised in its entirety, it will have improved heat-resistant and corrosion-resistant properties.

● *EXTRUDED AUTOMOBILE ENGINE PISTONS*

It is reported that extruded automobile engine pistons of aluminium alloy have successfully passed the trial stage. This new piston type is claimed to be up to 50% stronger and up to 30% lighter than conventional pistons. The new piston is made by an impact-extrusion process and heat-treated for a 100 to 200% increase in tensile strength, greater ductility, and more than 400% increase in fatigue life. Moreover, it is predicted that one operator, using the new process, would be able to produce some 500 pistons per hour, as compared with 100 to 200 per hour by present-day casting techniques. In the new impact-extrusion method, suitable dies are placed in a press and slugs of aluminium alloy are fed into the press which produces the piston extrusion. It is claimed that the extrusion method produces closer tolerances, in addition to the better physical properties mentioned above, and that the structure of the extruded metal is superior to that produced in the casting process. The various stages of producing pistons by the new process are as follows :— Slugs of proper size are cut from bar stock, either by saw or by abrasive wheel, and heated in a rotary-hearth furnace or induction equipment. At the same time, the extrusion die in the crank-type hydraulic press is preheated by means of a gas torch. The hot slugs are then transferred to the die and extruded, using graphite grease as lubricant. The piston is then freed from flash, heat-treated, and finished by machining.

● *PRODUCTION OF ROLLED STRIP FROM IRON POWDER*

For the production of rolled strip from iron powder, a carrier band, pre-coated with a layer of powder, is fed through a pair of rolls at rolling speed. In carrying this process into practice, it has been found that the usual considerations concerning rolling-mill design do not apply. In the rolling of steel, the roll diameter is usually about ten times the thickness of the material for rolling where it enters the rolls. It is only with thin and wide sections, mainly sheet and strip,

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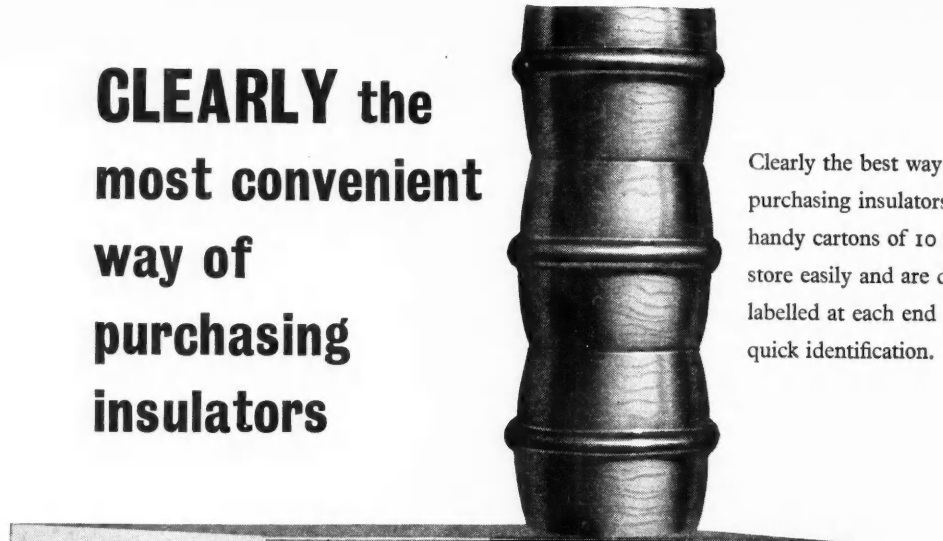

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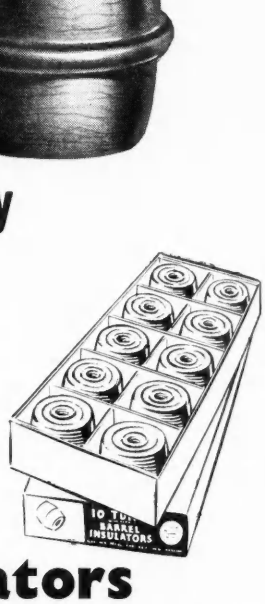

Manganese bronze insets tapped $\frac{3}{8}$", $\frac{1}{2}$" or $\frac{5}{8}$" Whit. Manganese bronze fixing stems can also be supplied.
In "Kite" Brand Tufnol for use in temperatures of up to 212°F. Tensile breaking stress approx. 8,000 lb. In "Asp" Brand Tufnol for temperatures ranging from 212°–392°F. Tensile breaking stress approx. 7,000 lb.

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that it is essential to make the diameter considerably greater, because of the required strength of rolls and roll journals. Large roll diameters are, however, basically undesirable, because they flatten, rather than draw, the rolled material. In many cases it is therefore preferred to retain small roll diameters and to support the thin rolls by thicker supporting rolls. For the rolling of powder the opposite applies, as claimed in a recent patent, and the roll diameter should therefore be at least fifty times, but preferably a hundred or more times, the thickness of the cross-section to be rolled. It appears that, in this connection, shape and size of grain play a part; the more the grain shape approaches spherical form, the greater must be the roll diameter. Similarly, the more irregular is the grain surface, the smaller can be the diameter of the roll. In order to ensure satisfactory introduction of the powder into the roll gap, the surface of the rolls should not be smoothly finished, but should be slightly roughened.

● *RESISTANCE-WELDING CONTROL*

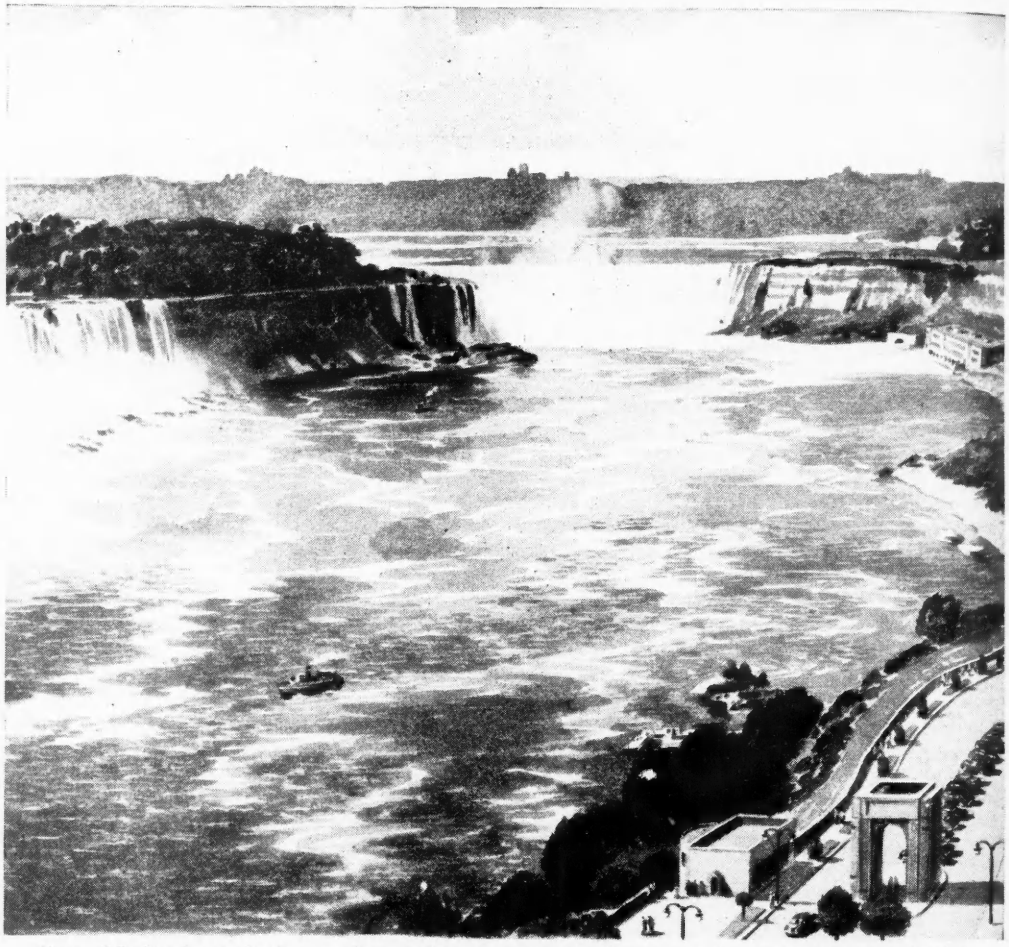
A new system of resistance-welding control has been developed, consisting of control units which can be combined to build up at least 180 different arrangements of welding sequence, to cover every possible welding requirement. This control equipment can be used with all types of spot-, seam-, and projection-welding machines. It is claimed that this equipment will considerably increase the range of functions which can be carried out by existing welding machines and will provide them with accurate electronic control. This would appear to be particularly important in cases where new or difficult materials have to be welded or where complex welding cycles are required. With the new control, operator fatigue, which so frequently is a cause of inconsistent weld quality, should be eliminated, because, once set, the operation of the equipment is fully automatic throughout each successive welding cycle. The fact that this equipment makes it possible to control separate functions, both in time and amplitude, should make it a useful tool for welding development work; it would enable the research and development engineer to establish precisely the correct welding cycle required for any given operation, and the requisite settings could then be duplicated on the production unit.

● *INVESTIGATION OF CYCLIC THERMAL STRESSES*

In cases where very high rates of heat transfer exist, severe thermal stresses can be developed in metallic structures. These stresses can be relieved by plastic flow and consequently are not regarded as serious where steady-state conditions prevail. Under the action of thermal oscillations, however, cyclic thermal stresses are produced. Depending upon the frequency of the thermal cycles and the severity of the thermal stress, fatigue failure can result. There is a number of cases in gas-turbine practice where cyclic thermal stresses must be considered, but perhaps the most serious case is that of the nuclear reactor. Here, the intense conversion of nuclear to thermal energy produces thermal fluxes which are many times those encountered in conventional heat-transfer systems. Because of their low thermal conductivity and high thermal expansion, austenitic stainless steels are especially endangered, and an experimental study on an 18% Cr, 8% Ni steel was therefore recently made with the use of a specially designed device for placing the material under stress with thermal cycling. The essential feature of the testing device consists of rigidly attaching a test specimen between two fixed plates, so that any longitudinal thermal deformation of the specimen is directly converted to elastic or inelastic deformation. To develop a cyclic thermal stress in the specimen, the latter is made to serve as its own heater, by passing a closely timed intermittent electric current through it. This apparatus is reported to have proved highly satisfactory, and it would appear that it could be employed to advantage in studying thermal expansion fatigue problems of a far wider range than originally contemplated.

● *MEASUREMENT OF DIFFERENTIAL PRESSURES*

A helical sensing element has been developed for the measurement of high-range differential pressures. Unlike the conventional single-turn Bourdon-tube elements, the new design employs a series of coils made from heavy-walled tubing, flattened and wound in helical form. The high pressure is admitted to the helical element itself, while the lower pressure is applied to the outer housing containing the helical element. The difference in pressure between the inside and the outside of the element causes the coil to wind or unwind, and the angular motion produced is transmitted to a pen or pointer by means of a sealed bearing and pick-up mechanism. For straight pressure measurement a heavy-duty helical design permits operation in extreme pulsating service; possible ranges of measurement include 0 to 50 up to 0 to 80,000 psi. The instrument is so designed that the spring motion is distributed over a series of coils, thus reducing the resulting stresses and increasing fatigue life. The number of coils employed is dependent on the amount of rotation required for the pressure range selected, with allowance for over-range. The maximum pressure which each element is intended to withstand governs the selection of tube-wall thickness and form. It is stated that stainless-steel tubing possesses the necessary spring characteristics over a wide range, with negligible hysteresis, so that accuracy and constancy of measurement are ensured.



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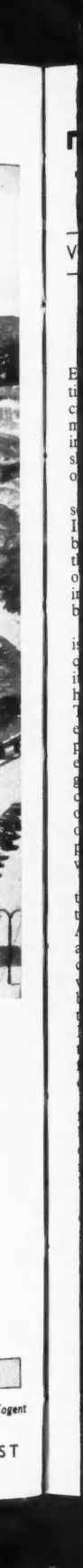
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